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GENERATION OF OIL BY GEOLOGIC DISTILLATION DURING MOUNTAIN-BUILDING[1]

JOHN L. RICH
Ottawa, Kansas

ABSTRACT

In regions of intense mountain-folding carbonaceous shales have lost the oil which, presumably, they once contained in the form of "kerogen" or similar mother-substance, and which is still present in equivalent rocks outside the metamorphosed zone. What became of this oil? The newer information on mountain-building indicates that folding commonly took place at considerable depth underneath great overthrust sheets of rock. Under such conditions it is believed that the oil was distilled from the carbonaceous rocks in what was, virtually, a giant high-pressure cracking still, and that it found easiest escape laterally along the bedding, being driven out to cooler zones by the gases generated during the distillation.

In later geologic ages the overthrust sheets became worn away and the whole area broadly uplifted, bringing the rocks formerly subjected to distillation up to the surface and opening their porous beds to the inflow and artesian circulation of meteoric waters which caused extensive secondary migration of the oil.

In the zone of intense metamorphism no oil would remain, the carbonaceous rocks would be devolatilized, and carbon ratios would be high. In an intermediate zone where the rocks are partly devolatilized, some of the oil would have been distilled in place, and some would have migrated from adjacent zones of more intense metamorphism. In a broad belt outside the zone of active distillation such oil as is found would not have been formed *in situ*, but would have migrated from adjacent zones of distillation under the influence of gas pressure and artesian circulation.

INTRODUCTION

One of the fundamental unsolved problems of petroleum geology is the source of the oil: whether formed close to the place where it is found or generated in certain areas under special conditions and later distributed widely to its present resting places. The problem is intensely practical,

[1] Read before the Association at the Tulsa meeting, March 26, 1927. Manuscript received by the editor September 1, 1927.

because on its solution depends an effective scientific search for regions most likely to produce oil.

In the present tendency toward acceptance of the theory that oil does not travel very far from its source, one of the most obvious and one of the most competent of the possible causes for the generation of petroleum and natural gas in large quantities appears to be either almost entirely forgotten or classed among the theories which are too preposterous to deserve serious consideration. I refer to the large-scale distillation of petroleum as an incident of mountain-making crustal movements, and its later wide dissemination through the rocks to its final resting-places, perhaps hundreds of miles from its source.

The ideas here presented were in considerable measure anticipated in a paper by Bailey Willis,[1] and are in part an outgrowth of a conversation with A. C. Veatch, who has been thinking along similar lines and to whom I am indebted for stimulating suggestions, but who is in no way responsible for any shortcomings of the theory as here presented.

In the light of the more recent studies of mountain structure and of the broader geologic relations which prevail during mountain-building and subsequently, the theory of geologic distillation of petroleum merits renewed consideration.

In regions of intense mountain-folding carbonaceous rocks have be-become devolatilized; coals have been changed to the higher bituminous grades or to anthracite; and bituminous shales, once "oil shales," have lost their oil. In this process enormous quantities of volatile hydrocarbons —oils and gases—must have been produced. They are not now found in the metamorphosed regions. Where are they? They evidently have escaped to points outside of the zone of distillation. Such escape may have been upward to the surface or laterally along the bedding to adjacent regions outside the influence of the metamorphism.

In seeking the bearing of these facts on the question of the origin of oil deposits it is important to visualize the geologic conditions under which the distillation occurred. This leads directly to the theory of mountain-building and to consideration of the geologic events preceding, during, and following the elevation of a typical mountain range.

HISTORY OF A TYPICAL MOUNTAIN RANGE IN RELATION TO DISTILLATION OF HYDROCARBONS

1. *Stage of sedimentary accumulation.*—A preliminary stage in the history of most great mountain chains seems to be the accumulation of a

[1] Bailey Willis, "Geologic Distillation of Petroleum," *Mining and Metallurgy* (January, 1920), No. 157, Sec. 10, 7 pp.

thick series of dominantly shallow-water rocks in a deep geosyncline in or on the borders of which the mountain-building is later localized (Fig. 1, A). These geosynclinal sediments, partly because of their shallow-water origin, are commonly carbonaceous, and locally highly bituminous. It is possible that more or less gas and oil are generated in these sediments by biochemical agencies as they are laid down and subsequently, previous to any dynamic metamorphism.

2. *Period of mountain-building.*—The more thoroughly mountains are studied, the more certain it becomes that the dominant element in mountain-building is large-scale overthrusting by which great slices of the earth's crust are thrust forward and up and piled one upon another, overriding, folding, and crumpling weaker rocks which happen to be caught beneath (Fig. 1, B).[1]

This condition may be illustrated by the southern Appalachians[2] and the Ouachita Mountains. In the former the thrusts came from the east and southeast; in the latter, from the south. In the southern Appalachians the remaining structures and the exposed thrust planes indicate that great thicknesses of rocks thrust from the east overrode, and were piled upon, the sediments of the Appalachian geosyncline which bordered the thrust zone on the west. Such a piling up of sheet upon sheet of rocks presumably built up a high mountain mass over the site of the buried sediments and, on the principle of isostasy, must have led to settling of the overloaded area,[3] carrying the sediments buried under the overthrust mass deep into the earth's crust, into a zone of relatively high temperature and pressure (Fig. 1, B).

3. *Stage of distillation.*—While the sediments of the geosyncline were being buried under thrust sheets from outside, crumpled and folded in the process, and sunk deeper and deeper into the crust under the load of the thrust sheets piled up above them,[4] conditions are believed to have been

[1] No attempt is here made to cite the many references to the literature of mountain-thrusting. For brief summaries, with bibliographies, see Bailey Willis, *Geologic Structures* (New York, 1923), chap. v, and R. A. Daly, *Our Mobile Earth* (New York, 1926), chap. vi.

[2] See *U. S. Geological Survey*, folios of southern Appalachian region; also Arthur Keith, "Outlines of Appalachian Structure," *Bull. Geol. Soc. Amer.*, Vol. 34 (1923), pp. 309–80.

[3] Albert Heim, "Das Gewicht der Berge," *Jahrbuch des Schweizer Alpenclub*, 53 Jahrgang, 1918.

[4] Whether the process was overthrusting or underthrusting, as urged by Hobbs, Lawson, and others, is immaterial to the present problem. See Herbert Hobbs, "Mechanics of Formation of Arcuate Mountains," *Jour. Geol.*, Vol. 22 (1914); A. C. Lawson, "Folded Mountains and Isostasy," *Bull. Geol. Soc. Amer.*, Vol. 38 (1927), pp. 253–74.

most favorable for devolatilization of carbonaceous rocks and the generation of oil and gas. The sediments would have been caught in what would have been essentially a high-pressure cracking still. They would have been subjected to these conditions for a very long time, so that in favorable situations, complete devolatilization and distillation of the carbonaceous rocks might occur.

What would become of the products of distillation under such conditions? Two forces would tend powerfully to drive them out of the zone of distillation: heat, and the pressure of the gases evolved. Two evident paths of escape would be (1) upward to the surface, and (2) laterally along the bedding of the sediments. The upward path would require movement crosswise of the bedding and of the overthrust sheets. Consideration of the probable presence of the overthrust sheets makes upward escape seem much more difficult than would be the case if distillation occurred near the surface where the rocks are now found. Under the supposed conditions of deep burial, the path of escape laterally along the bedding of the sediments appears to be the easier. Jointing and faulting in the folded and crumpled zone might afford means by which the products of distillation could gain access to such members of the sedimentary series as would afford the easiest paths of escape. Fracture planes, joints, and bedding planes would probably play an important part in this migration, particularly in the more brittle members of the section.

In thinking of the possibility of lateral migration away from the zone of distillation it is important to bear in mind (1) that the migration would undoubtedly be backed by very high gas pressures; and (2) that heat and dissolved gases greatly lower the viscosity of oils[1] and make their movement through minute openings much easier than it is under surface conditions.

4. *Period of erosion.*—After mountain-building has ceased, there comes a period during which the mountain forms are eroded away, the overthrust sheets are worn off, and the folded and crumpled sediments below them are gradually brought to light. This process of erosion is commonly carried so far that the former mountains are reduced to a peneplain, and the process may be repeated several times if periodical uplifts occur, as is attested by remnants of peneplains of several stages found on the summits of most mountain ranges in the later stages of their physiographic history.

[1] C. E. Beecher and I. P. Parkhurst, "Effect of Dissolved Gas upon the Viscosity and Surface Tension of Crude Oil," *Petroleum Development and Technology in 1926*, pp. 51–69. New York: Amer. Inst. Min. and Met. Eng., 1927.

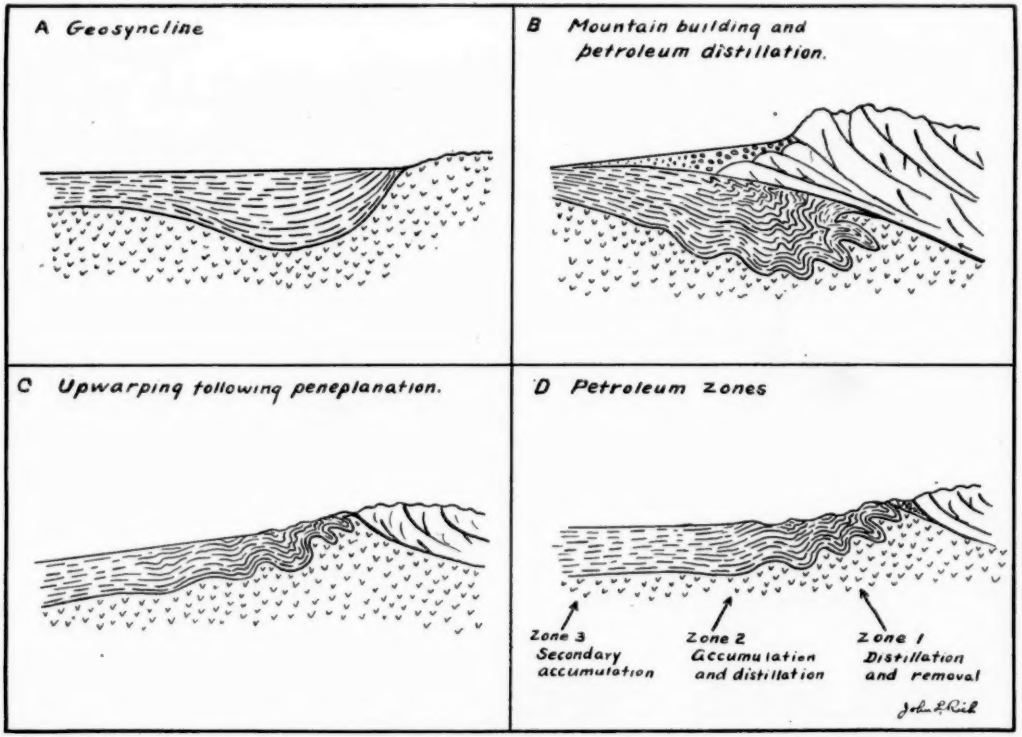

A Geosyncline
B Mountain building and petroleum distillation.
C Upwarping following peneplanation.
D Petroleum zones
Zone 3 Secondary accumulation
Zone 2 Accumulation and distillation
Zone 1 Distillation and removal
John P. Rich

FIG. 1.—Diagrammatic sketches illustrating stages of mountain development and evolution in relation to the generation of oil by geologic distillation. Vertical scale highly exaggerated. *A*, accumulation of thick series of bituminous sediments in sinking geosyncline. *B*, mountain-building and piling up of thrust sheets over geosynclinal sediments, accompanied by isostatic sinking. Generation of oil by heat and dynamic movements. *C*, regional upwarp after peneplanation. *D*, petroleum zones.

5. *Period of regional upwarp.*—Following one or more stages of partial peneplanation, it seems to be the general fate of mountains, for some reason not yet fully known, to suffer a broad regional upwarping, so that the present relief of the majority of mountain regions, for example, the Appalachians, is not at all due to the original mountain folding (Fig. 1, C).

During the periods of peneplanation and, in many instances, repeated regional uplift and erosion, the sedimentary rocks which during the mountain-building stage were deeply buried and subjected to strong metamorphic action are elevated and their cover worn off, so that finally they are exposed at the surface with a regional dip away from the former mountains. This exposes the edges of the strata to meteoric waters which set up an artesian circulation directed, in general, outward from the uplifted area.

The regional uplift of the former mountain area and the establishment of an artesian circulation must necessarily lead to widespread readjustments of the rock fluids, with a general tendency toward movement away from the mountain region. In the course of this readjustment oil and gas which had accumulated along the borders of the mountain belt outside the zone of metamorphism and distillation would be shifted, rearranged, and carried forward with the shifting rock fluids. Such movements might be complex and might be carried on continuously or intermittently during succeeding geologic ages and under varying physiographic conditions, the oil accumulating, perhaps, in favorable traps, only to be flushed out and carried farther in later stages of physiographic evolution. In this way the final resting-place of the oil might be a long way from its source.

As has already been suggested, in thinking of such secondary oil migration it is important to keep in mind the effects of heat and dissolved gases in greatly increasing the mobility of the oil.

ZONES OF OIL DISTILLATION AND ACCUMULATION

For convenience, three zones may be thought of as extending outward from the seat of mountain-building and active distillation. These must, of course, merge into each other with all gradations between them (Fig. 1, D).

1. *Zone of distillation.*—This is the zone of intense dynamic metamorphism where distillation has been more or less complete. In it, bituminous rocks have been devolatilized, carbon ratios are high, and no oil, or only a small amount of high-grade oil with a little gas, remains.

2. *Zone of partial distillation and "in situ" accumulation.*—In this zone the rocks have been partly devolatilized, carbon ratios are medium, and oil is plentiful. Part of this oil may have been formed by distillation in place or very close to its point of accumulation. Part of it has migrated into this zone from the adjoining regions of more complete devolatilization.

3. *Zone of secondary migration and accumulation.*—This zone includes all of the area outside of that in which active dynamic distillation occurred. The rocks are little altered; bituminous shales remain in the form of "oil shale"; carbon ratios are relatively low; and oil becomes, in general, less and less plentiful with distance from the point of original distillation. Such oil as is found has not been formed *in situ*, but has migrated to this zone either (1) during mountain-building and its accompanying distillation, under the influence of gas pressure generated by the distillation, or (2) subsequently, under the influence of artesian circulation and the general rearrangement of rock fluids.

ZONAL VARIATIONS IN THE CHARACTER OF THE OILS

In a general way the nature of the oil from each of the three zones would be peculiar to its zone.

In Zone 1 the only remaining oil would be a light end-product of the distillation trapped and protected from flushing by circulating water. In Zone 2 oils of average good grade would predominate, modified locally under special conditions of accumulation or subsequent history. In Zone 3 the oils would be expected to have been considerably altered in the course of their more extensive migrations. They might have become lighter as a result of fractionation, but more commonly they would have become heavier on account of contact with oxidizing minerals or with sulphate waters.

As a generalization, the zone having highest carbon ratios would have light oils, and the zone having lowest carbon ratios would have heavier oils. Special oxidizing conditions might, however, yield heavy oils in any one of these zones.

BEARING ON CARBON RATIO THEORY

The theory here proposed has much in common with the carbon ratio theory proposed by White,[1] but it offers different explanations of some of

[1] David White, "Some Relations in Origin between Coal and Petroleum," *Washington Acad. Sci. Jour.*, Vol. 5 (1915), pp. 189–212; "Late Theories Regarding the Origin of Oil," *Bull. Geol. Soc. Amer.*, Vol. 28 (1917), pp. 727–34; "Genetic Problems Affecting Search for New Oil Regions," *Trans. Amer. Inst. Min. and Met. Eng.*, Vol. 65 (1921), pp. 176–98.

the facts which have commonly been associated with the carbon-ratio theory. Brief comparison of the two theories is made in the following paragraphs.

According to both theories, the original source of the oil is the dynamic metamorphism of the mother-substances of petroleum contained in the rocks. The existence of oil pools previous to metamorphism is not an essential part of White's theory, and is mentioned only incidentally by him, though it seems to be taken as an integral part of the theory by some of his followers and has been made the basis of serious criticisms of the theory.[1] According to the theory here proposed, the possibility of such pre-existing pools is recognized, but they would form no necessary first step in the process. Direct production of oil and gas from the mother-substances by destructive distillation and cracking under the influence of dynamic metamorphic conditions is the essence of both theories.

Under both theories the regions of greatest metamorphism would now contain no oil, or only minor amounts of high-grade oil and, possibly, gas. The reason for this general absence of oil is the same under both, namely, that the conditions which produced the metamorphism effectively drove the oil vapors out of the metamorphosed zone into bordering cooler regions, and that under cracking-still conditions the lightest oils and the gases are the products yielded in the later stages of the cracking.[2]

The fact that the limits of the region in which commercial oil pools may be expected happen to coincide with the 60 or the 65 isocarb means simply that the degree of metamorphism which altered the coals to this extent happens to have been the same as that which expelled the oil vapors more or less completely from the rocks.

A certain amount of correspondence between the degree of metamorphism and the grade of the oil, such as is stressed by White, would be expected under the theory here proposed because the lighter end-products of the cracking would tend to gather nearest to the regions of higher metamorphism. It is also recognized that the nature of the mother-substances and a complex series of interacting relations of temperature and pressure would influence the grade of the oils.

The theory here proposed would account for the heavier oils now found in the regions of lower carbonization, not as the original products

[1] George Edwin Dorsey, "The Present Status of the Carbon-Ratio Theory," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 455–65.

[2] See literature on destructive distillation of oil shales and on cracking; also Roswell Johnson, "The Relation of the Quality of Oil to Deformation," *Econ. Geol.*, Vol. 10 (1915), pp. 676–78.

of slight metamorphism, but as altered oils which have become oxidized in the course of their secondary migrations away from their sources. At the same time it is recognized that heavy oils might be produced in the early stages of metamorphism or in regions which have suffered only moderate degrees of metamorphism.

Recognition of the possibility of extensive secondary migration, with its attendant likelihood of changes in the gravity of the oil, makes it useless to attempt to tie up the gravities of the oils with the degree of metamorphism of the coals of the regions where the oil is now found, except in the regions of greatest metamorphism. Outside the latter, in the regions of lower carbon ratios—which are also the areas of secondary migration and accumulation, as outlined in this paper—oils of any grade, except possibly the highest, should be expected, and the presence of heavy oils beneath lighter oils should not be considered anomalous because, according to the theory here proposed, the gravity of the oils in these areas is not dependent upon the carbon ratios, but rather on the chemical conditions which the oil has encountered in its containing reservoirs and on its migrations to them.

Likewise, in areas of slight metamorphism the gravities of the oils should not be expected to be related to the age of the strata in which they are now found. If, as White has urged,[1] it is dynamic metamorphism associated with mountain-building which devolatilizes the coals, it is presumably the same dynamic metamorphism which produces the oils and drives them out of the most highly metamorphosed regions. For any particular period of diastrophism, nearness to the seat of the disturbance and the degree of stress endured would determine the amount of metamorphism, not the age of the strata involved. Therefore, following the argument here presented: from all strata subjected to severe metamorphism in any particular period of diastrophism the oils would have been driven out completely or only the lighter oils would have been retained, while in all strata in the outer zones of slight metamorphism—the zones of secondary migration and accumulation—the gravities of the oils would be controlled by the chemical conditions encountered on the road to their present resting-places.

APPLICATION OF THE THEORY

The theory of the origin, migration, and accumulation of oil outlined in preceding paragraphs is presented as a working hypothesis which may explain some of the puzzling problems of petroleum geology. The genera-

[1] David White, "Progressive Regional Carbonization of Coals," *Trans. Amer. Inst. Min. and Met. Eng.*, Vol. 71 (1925), pp. 253–81; *U. S. Bureau of Mines, Bull. 38.*

tion of large quantities of petroleum somewhat in the manner outlined seems to be almost a necessary result of geologic conditions which are now known to have been commonly associated with mountain-building. The lateral escape and later condensation of the petroleum vapors generated in the areas undergoing metamorphism should, it seems, have concentrated much oil and gas in belts outside the metamorphosed zone. Later shifting of rock fluids and the development of artesian circulation in later stages of physiographic evolution seems competent to have shifted some, at least, of this oil for long distances.

Study of the oil fields of the world with this hypothesis in mind would, it is believed, show that many of them are related, somewhat in the manner here outlined, to belts of dynamic metamorphism competent to have been the sources of the oil. Obviously the actual conditions in nature are complex, and it will doubtless be possible to point out oil deposits which do not seem to fit into the hypothesis. Obviously, also, there must be all degrees of metamorphism and geologic distillation, ranging from the stage of complete devolatilization to the stage in which no oil has been produced by distillation in place. As a consequence, some regions would contain oil generated in place by dynamic metamorphism of moderate intensity[1] too weak to drive it outward from its source; other regions would contain only such oil as had reached them by secondary migration.

The application of the theory to the Oklahoma-Kansas-Missouri-Iowa region may be sketched by way of illustration, but the reader is asked to bear in mind that a complete picture cannot be given in a few paragraphs. The region bordering the Ouachita Mountains on the north seems to satisfy the conditions postulated, namely, a thick geosynclinal series of carbonaceous sediments caught and subjected to cracking-still conditions and metamorphosed under the range overthrust from the south. Laterally in the beds involved in this metamorphism, but outside the metamorphosed zone, lie the rich oil accumulations of Oklahoma, where almost every member of the geologic sequence capable of serving as an oil reservoir is relatively highly saturated with oil. It is a region of exceptionally plentiful oil accumulation and corresponds to Zone 2 of the preceding classification, where part of the oil may have been distilled in place, but where much of it accumulated after being driven out of the more highly metamorphosed zone adjacent.

[1] See Alex W. McCoy, "Notes on Principles of Oil Accumulation," *Jour. Geol.*, Vol. 27 (1919), pp. 252–62; "A Short Sketch of the Paleogeography and Historical Geology of the Mid-Continent Oil District and Its Importance to Petroleum Geology," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 6 (1921), pp. 541–84.

Outside the Oklahoma belt of abundant oil accumulation lies the broad zone of secondary accumulation, embracing parts of Oklahoma, Kansas, Missouri, Iowa, and adjoining states. In this region it could, it is believed, be shown to be a general rule that the amount of oil in available reservoir rocks decreases with distance from the supposed source. In northeastern Kansas and adjoining areas many reservoir sands are found, but oil is scarce. Much of the oil, especially in the deeper sands, is heavy, presumably on account of oxidation by sulphate waters. It is doubtful if it could be shown that bituminous shales of the type commonly supposed to be the source of the oil under the theory of local origin make up less of the section here than in regions where more oil is found.

An application of the theory such as that presented in the preceding paragraphs can be only suggestive. It is not intended so much as proof as it is to suggest other similar applications and to serve as a guide in the search for pertinent facts having a bearing on the problem. Among the observations needed are large numbers of actual records showing the presence or absence of bituminous source rocks in close association with oil pools; all possible information on gravities of oil in relation to geologic factors likely to affect the gravity, such as character of the associated waters, unconformities, oxidizing sediments, and the possibilities of free or restricted fluid flow in the reservoir rocks; and, finally, a broad study of the world-wide distribution of oil in relation to localities where thick bituminous sediments have been metamorphosed in connection with mountain-making earth movements.

THE GOLDEN LANES OF GREENWOOD COUNTY, KANSAS[1]

W. K. CADMAN[2]
Wichita, Kansas

ABSTRACT

A critical examination of shore-line processes and shore-line development, when applied to conditions in the Golden Lanes of Greenwood County, Kansas, shows that the shore-line theory of origin of the sands is not applicable to conditions as revealed by the drill. The narrow sand bodies, the absence of a cliff or cliff-forming element, the irregular bottom of the sands, the complex cross-sections of the sands, the meandering of the trends, and branching of the trends cannot be accounted for by shore-line processes.

The evidence points to streams working over a valley-flat environment as the origin of the sand deposits of the Golden Lanes.

Structural geology, because it lacks consistency or trueness to form, is of no value as an index to the location of the trends, or to points where production may be found in the trends.

The present trends are but a part of a much greater system whose limits are yet to be found.

INTRODUCTION

The sand trends of the Golden Lanes of Greenwood County, Kansas, are from one-half to one and one-half miles in width and nearly 40 miles long, but the ends of the trends have not as yet been found. Along these trends are found many oil pools, strung out as links in a great chain, which form one of the most singular types of producing areas known to the oil industry. This very deviation from the ordinary in pool types is a constant challenge to one's curiosity as to the origin of the trends, and makes them worthy of attention and careful study.

In presenting these observations of the Golden Lanes, the area under observation is not confined to Greenwood County alone, but includes adjoining counties in which many interesting features have been revealed. For a detailed study of the problem a single township was worked in close detail. This area, T. 23 S., R. 9 E., was selected because (*a*) it is an area of typical trend development; (*b*) the finding of oil in commercial quantities has resulted in the drilling of many wells (total, 313) from which much detailed information has been derived; (*c*) the township is the only trend

[1] Presented by title before the Association at the Tulsa meeting, March 26, 1927. Manuscript received by the editor July 20, 1927.

[2] 118 N. Erie Street.

township in which, up to the present time, two major trends are located; and (*d*) within this township has occurred the developmental history of the Golden Lanes.

In studying a phenomenon buried many feet below the surface of the earth and revealed only by data from drilled wells it is obvious that the details revealed by the drill will be but a small fraction of those which might be obtained from a study of the same phenomenon at the surface of the earth. Consequently, in this study all that is available to us are the more general and pronounced features of the sand deposits; our information must be almost completely confined to a study of the top, the bottom, the distribution, and the cross-sections of the sand bodies.

As these trends have been interpreted as shore lines, and as a land mass and a sea are essential to shore-line development, it is well here to define them in relation to the sand trends in question. The only land mass known to have existed in proximity to the Golden Lanes at the time of their deposition is the buried granite ridge, the Nemaha Mountains, which lies west and northwest of the trend area under discussion. There may have been other land areas in existence besides the granite ridge when the Golden Lanes were laid down, but up to the present time their existence has not been revealed in or near the area of the trends. From the available data we correctly conclude that the granite ridge, with its foothills, was the land mass; east and southeast of the land mass were the shore lines, with the sea stretching to greater distances in the same directions.

EXAMINATION OF EVIDENCE BEARING ON THE SHORE-LINE THEORY

Resting upon, and stratigraphically unconformable with, the peneplaned "Mississippi lime" is the basal member of the Pennsylvanian system, the Cherokee shale. In the lower portion of the shale are three sands which are in most places easy to recognize, and of economic interest because they carry oil. In contact with the "Mississippi lime" and at the base of the Cherokee shale is the Burgess sand, which produces some oil in such places as the Weirshing pool, Sec. 23, T. 26 S., R. 9 E. Above the top of the "Mississippi lime," at an average interval of 135 feet, is the Bartlesville sand—the producing sand of the Golden Lanes. At an average interval of 80 feet above the top of the Bartlesville sand is the Cattleman sand, which is the producing horizon of such pools as the Wiggins pool, Sec. 30, T. 24 S., R. 11 E., the Christy pool, Sec. 9, T. 25 S., R. 11 E., the Hollis pool, Sec. 16, T. 23 S., R. 10 E., and the Burkett pool, Sec. 12, T. 25 S., R. 8 E. Although some geologists are inclined to combine the Burgess sand, the Bartlesville sand, and the Cattleman sand into the

Bartlesville group, such a classification is not made in this study. The Bartlesville sand is here considered exclusively.

Prior to the deposition of the Cherokee shale, the "Mississippi lime" had been planed down to a peneplain of moderate relief. A study of the present surface indicates a maximum relief of about 200 feet, but as the surface is the result of irregular erosion, followed by some warping due to folding and differential settling, it is quite possible that the original relief was somewhat less than 200 feet, maximum.

At no place outside of the granite ridge area has a "Mississippi lime" high been found high enough to cut out the Bartlesville sand, although in places the sand has been found deposited in contact with the lime. With an average interval of 140 feet from the top of the Bartlesville sand to the top of the "Mississippi lime," and an average thickness of 30 feet for the Bartlesville sand, we have an average maximum relief of about 100 feet for the peneplaned surface.

As to whether this eroded plane is the result of fluvial planation or marine planation, the information is not conclusive. Our knowledge of the relation between land and sea during the late Mississippian and early Pennsylvanian periods makes it seem most likely that the peneplain is due to both aerial and marine erosion. This much is known: during this period of alternate submergence and emergence the sea was compelled to work over a plain of great area and of moderate relief.

If the peneplaned surface of the "Mississippi lime" was preserved during the deposition of the early Cherokee shale, any shore line formed in the shale should have the profile of the normal shore line of emergence[1] during the periods of emergence. On account of the peneplaned surface, shore lines formed during the periods of submergence will not have the profile of an irregular shore line of submergence, but will have an initial profile resembling that normally characteristic of a shore line of emergence, and the history of development will be that for such a profile.

The basal members of the Cherokee shale seem to have been deposited conformably upon the peneplaned surface of the "Mississippi lime," and in all probability the plain surface has been substantially reflected in the successive layers of the shale. Therefore any shore lines that may have been formed belong to the coastal-plain type of shore lines of emergence.

An important characteristic of the sand deposits of the Golden Lanes

[1] For characteristics of shore lines of different types at various stages of development, see standard textbooks and especially D. W. Johnson, *Shore Processes and Shoreline Development*, J. Wiley & Sons. Familiarity with these features is assumed in the following discussion. Johnson's terminology is used.

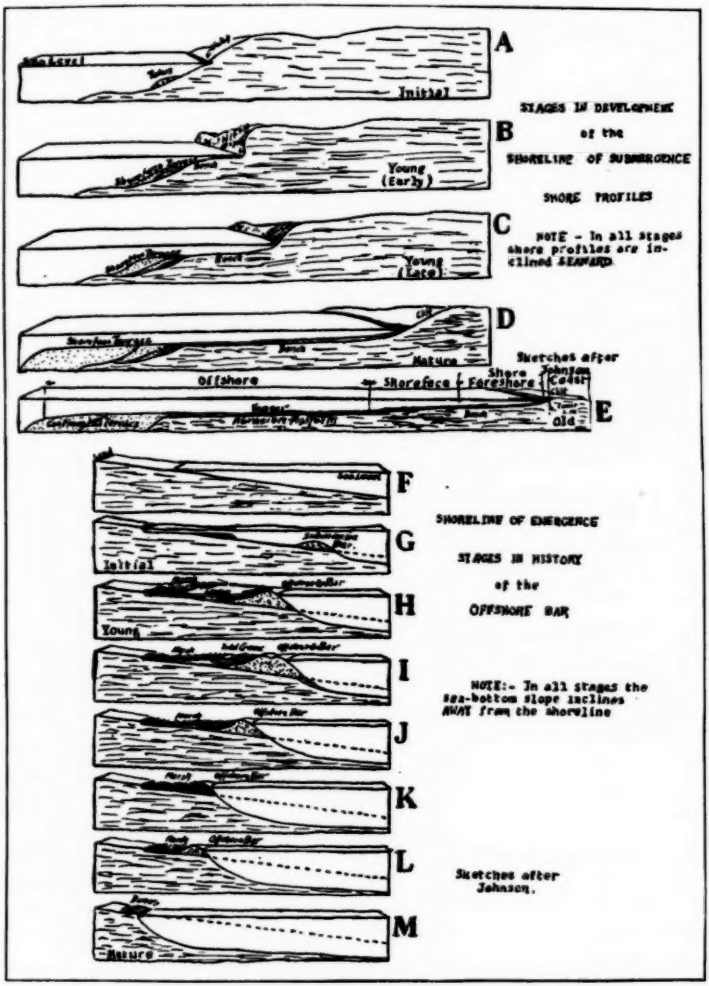


FIG. 1.—Shore profiles at different stages in shoreline development. (After D. W. Johnson.)

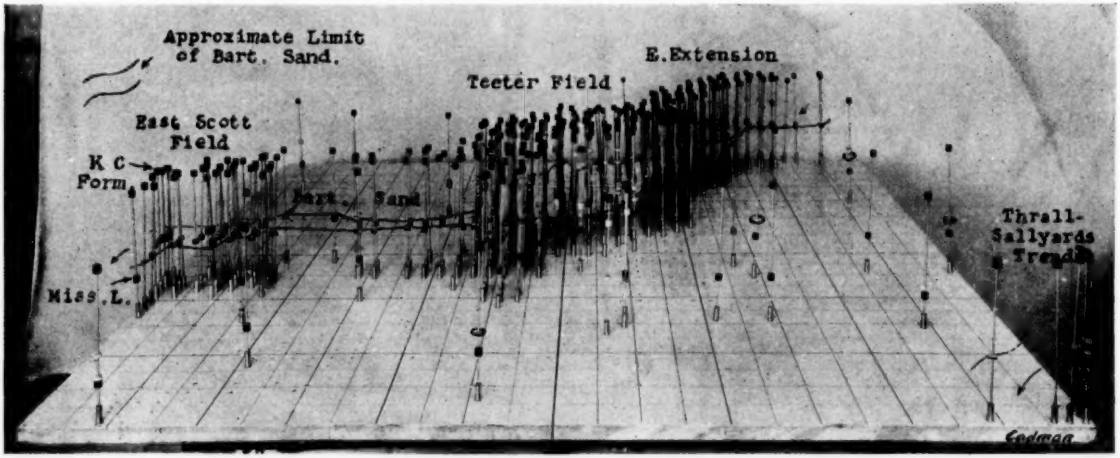


FIG. 2.—Phantograph model (patent applied for) of T. 23 S., R. 9 E., Greenwood County, Kansas. Shows the narrowness of the (Teeter) trend of sand. Notice the few wells having Bartlesville sand between the Teeter trend and the Thrall-Sallyards trend.

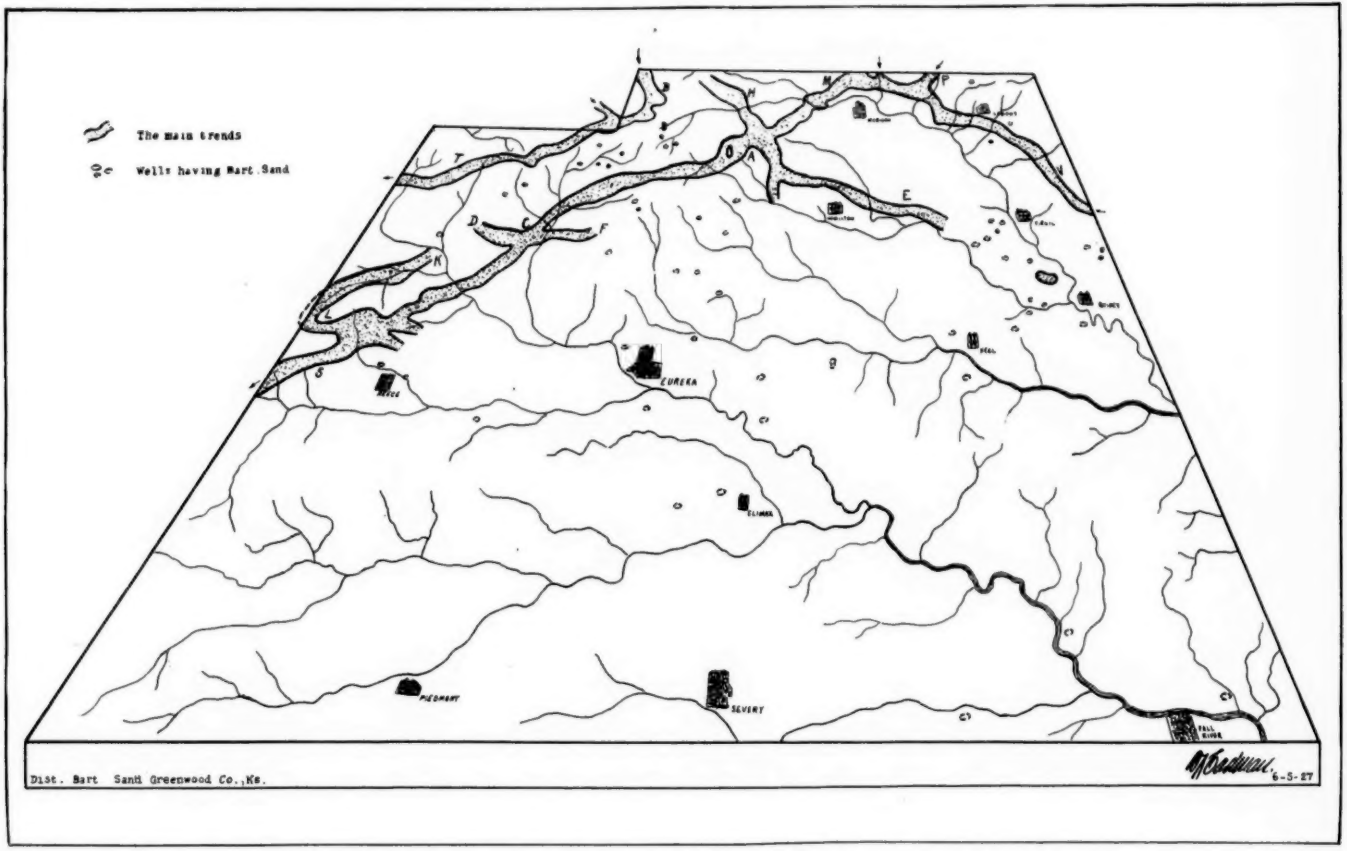


FIG. 3.—Perspective sketch showing the Golden Lanes of Bartlesville sand in Greenwood County, Kansas

is the regularity of the sand margins (Fig. 2). A glance at Figure 3 will show a noticeable absence of features typical of a shore line of submergence.[1] There is no evidence of an exceedingly irregular shore line, numerous branching bays, or drowned valleys, or many projecting peninsulas. The crenulate shore line is not in evidence; neither are beaches, such as headland beaches, bay-head beaches, or bayside beaches. Embankments, in the form of spits, bay bars, bay-mouth bars, bay-head bars, winged headlands, and tombolos, are not recognized. The sand deposits are not wide.

An important feature common to both the shore line of submergence and the shore line of emergence is that the normal profile has a comparatively steep slope descending rather abruptly into the water (shore line of submergence), or the subaqueous plain of deposition (shore line of emergence) normally has a surface gently inclined away from the shore line. A glance at Figure 4 will show that the cross-sections of the sand do not conform to this important feature, even if allowances are made for the present regional dip. In cross-sections B, E, and G the sand obviously slopes shoreward; in sections C (when corrected), D, and H, it can be interpreted as sloping seaward; in sections A and F it slopes both ways.

Furthermore, a point on the base of the sand deposit at the shoreward margin should be higher than a corresponding point at the seaward margin and perpendicular to the shore line. Under normal conditions the sand deposits should increase in thickness from the shore to the sea, that is, the average thicknesses of the seaward deposits should be greater than those of the shoreward deposits. The exceptions to this situation are seen where sand dunes lie along the coast and where the submarine bar or the offshore bar is present.

A careful study of Figure 5 will show a very complicated relationship between the two margins of the sand deposits. Even though allowances be made for the slight regional dip across the trend, it is found that sands along the north and northwest margin of the trend are lower or higher and thicker or thinner than sands along the south and southeast margin. It is quite obvious that conditions here do not conform to the features to be expected along a shore line.

A study of the Bartlesville zone in T. 23 S., R. 9 E., shows an absence of a cliff or cliff-forming element on the landward margin of the trend. The depositional sequence along the north and northwest margin is practically the same as along the south and southeast margin.

Of the 313 wells drilled in the township, 220 (70.27 per cent) show

[1] D. W. Johnson, *op. cit.*

FIG. 3.—Perspective sketch showing the Golden Lanes of Bartlesville sand in Greenwood County, Kansas

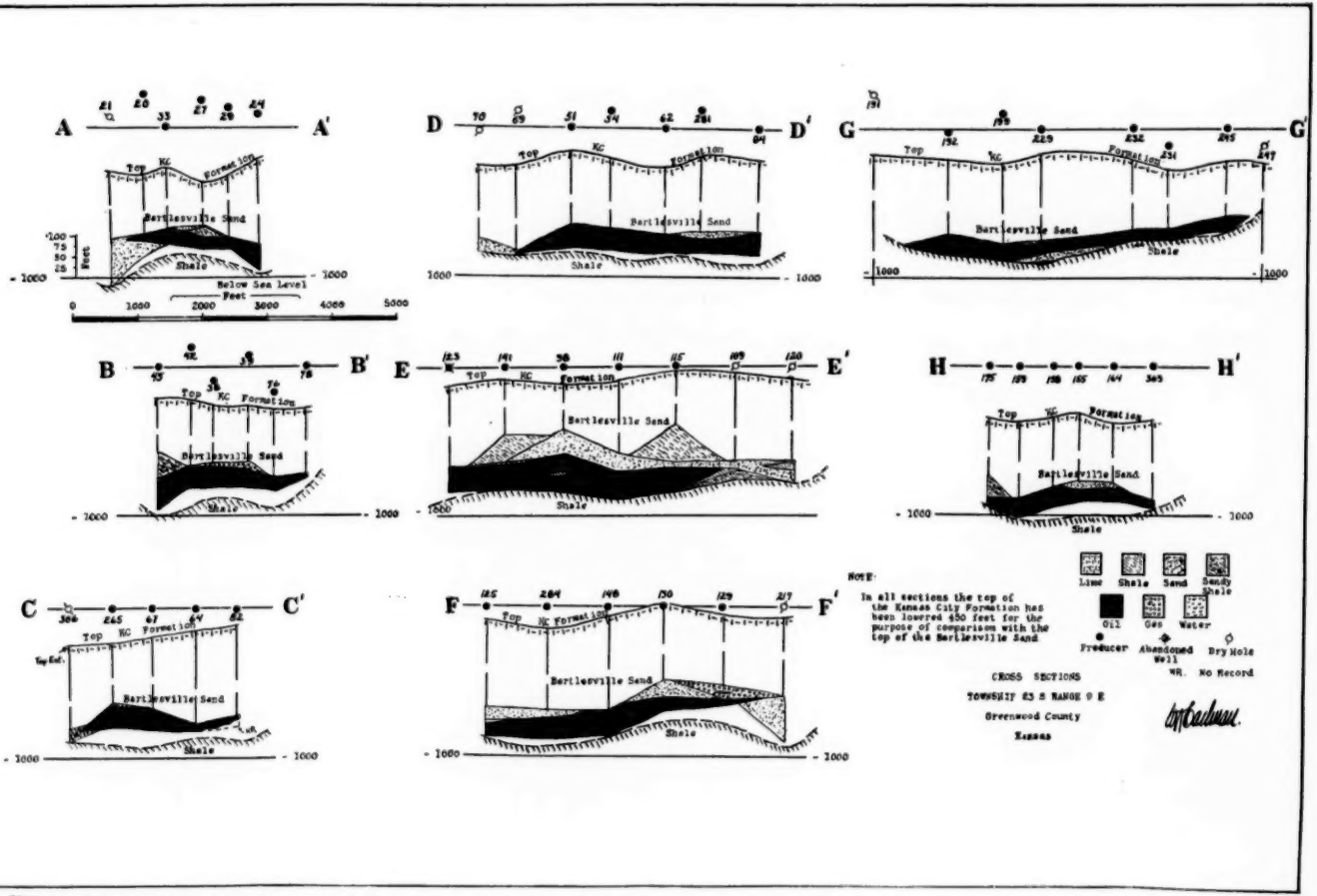


FIG. 4.—Cross-sections of the Tester trend, T. 23 S., R. 9 E., Greenwood County, Kansas. (See Fig. 2.) Space between the base of the drilled portion of the sand

shale in contact with the top of the Bartlesville sand. In the Teeter trend, 59 (18.84 per cent), the Thrall-Sallyards, 4 (1.28 per cent), and outside of the trends, 6 (1.92 per cent) show sandy shale in contact with the sand. Red rock is in contact with the sand or sand zone in three places, two of which are in the south and southeast margins.

Lime in contact with the Bartlesville sand is indicated in twenty-one places, two of which are outside the trends, and nineteen identified with the Teeter trend. Of the nineteen wells showing lime in contact with the sand, two are in the south and southeast margin, and three are in the north and northwest margin. Seventeen are scattered through the trend.

The shales along the two margins of a trend do not show the differences in character which would be expected along the opposite sides of a coastal sand strip.

From this study of depositions we can be safe in concluding that there is neither a pronounced cliff nor a low and inconspicuous cliff associated with the sand deposits of the Golden Lanes.

If the shoreward margins of the trends were really cliffs, but so small and inconspicuous as to be masked by subsequent deposition, the sand deposits seaward from the cliffs should have widths ranging from a few to many miles. The continental shelf facing a

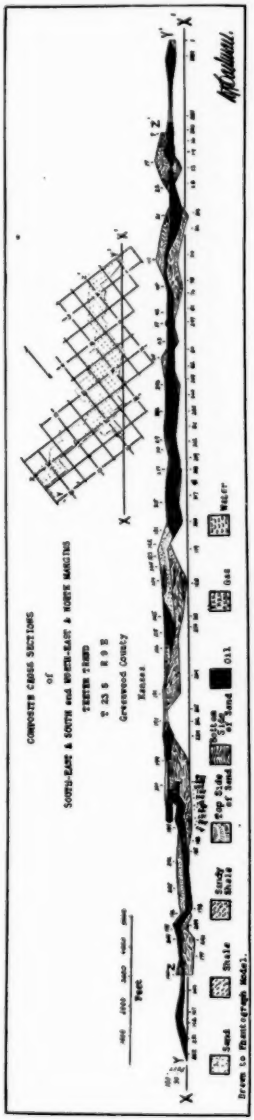


FIG. 5.—Composite cross-sections of the southeast and south, and the northwest and north margins of the Teeter trend, T. 23 S., R. 9 E., Greenwood County, Kansas. Where the sand of the northwest and north margin extends above or below the southeast and south margin, the top surface of the sand above, and the bottom surface of the sand below, is shown.

coastal plain is generally very wide and is mostly covered with sand. Murray[1] reports that the deposits formed between the shore and the continental shelf, estimated as covering at present about 10,000,000 square miles, consist mainly of finer sands, and more rarely of muds which are washed from the shore.

It is hardly likely that the narrow sand deposits of the Golden Lanes, with no evidence of cliffs, and laid down upon a broad plain, are the result of shore-line processes. Where we should reasonably expect deposits several miles in width, we have sand bodies ranging from one-half mile to one and one-half miles in width.

It may be held by some that the Thrall-Sallyards trend is an offshore bar to the Teeter trend. An examination of the data will show that such a conclusion is made on untenable ground. Figure 6 represents a reconstructed cross-section between the two main trends. Line R_1–R_2 is drawn so as to conform as nearly as possible to the regional dip, as well as to cross the trends on a line perpendicular to their axes. As line R_3–R_4 (Fig. 7) is drawn perpendicular to line R_1–R_2, it coincides with the regional strike.

If the Thrall-Sallyards trend is an offshore bar to the Teeter trend, or even parts of a single shore line, then a line *B B B* (Fig. 6) drawn through the average base of the Thrall-Sallyards deposit in its original position should be a straight line projection of the line *A A A* which is drawn through the average base of the Teeter deposit in its original position. The reconstructed cross-section shows the relation between the sands in the two trends.

A study of the formations in the Bartlesville zone between the Teeter and the Thrall-Sallyards trends does not point to the presence of a lagoon. According to Twenhofel,[2] the environment and sediments of a marginal lagoon are fine sands, silt, clay, and young shells from the sea. Shallow depths in the lagoon favor plant growth, and presence of vegetation favors the presence of marine animals, although the latter may be small or dwarfed on account of the character of the water. Calcium carbonate is precipitated by plants and animals living in the water. Stratification should be regular and even, except near openings of the bar and near the mouths of streams flowing into the lagoon. Colors of sediments range from gray, where vegetation is sparse, to dark, where it is abundant.

Of the many wells drilled between the trends, sixteen have had Bar-

[1] A. W. Grabau, *A Comprehensive Geology*, Part I, p. 549.

[2] W. H. Twenhofel, *Treatise on Sedimentation* (Baltimore: Williams & Wilkins Co., 1926), p. 602.

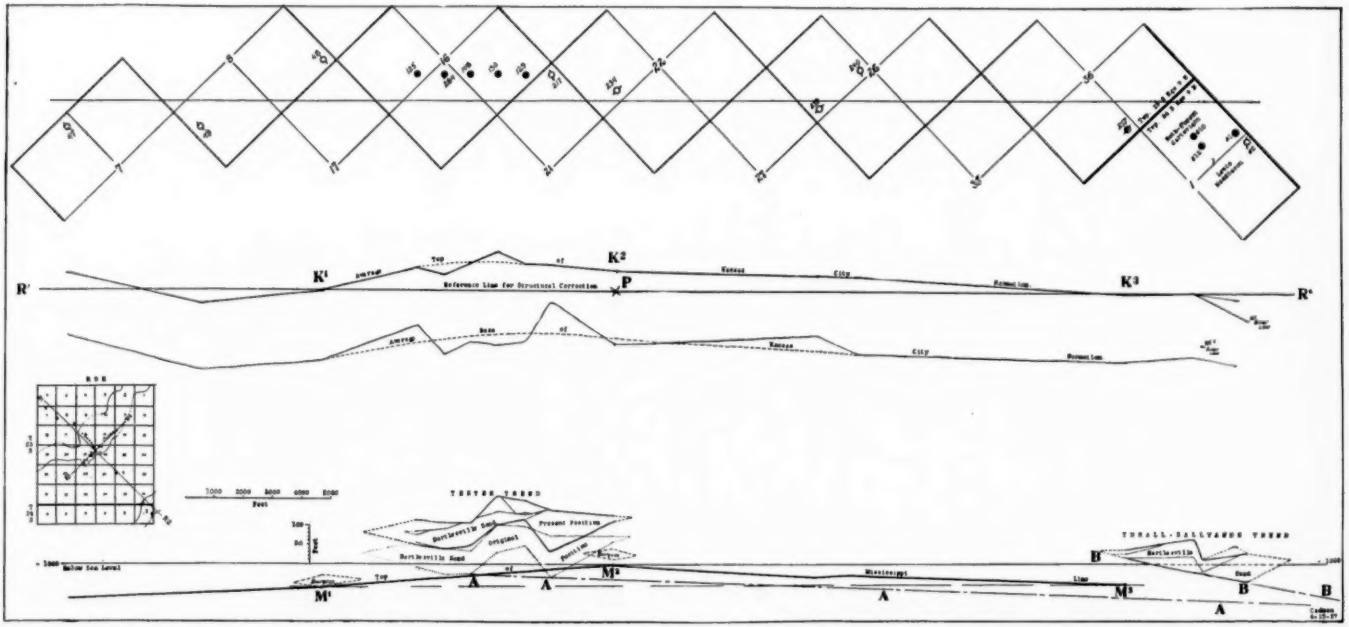


FIG. 6.—Reconstructed cross-section between the Teeter and the Thrall-Sallyards trends, Greenwood County, Kansas

tlesville sand—probably eolian—ranging from 5 to 25 feet in thickness; a few have had sandy shale in the Bartlesville zone; and most of them did

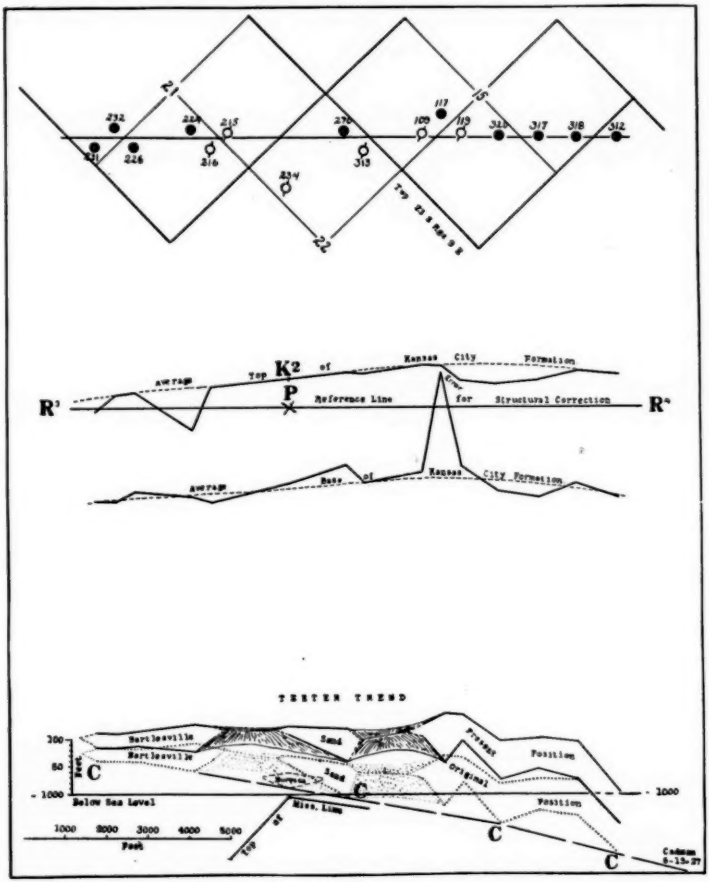


FIG. 7.—Reconstructed cross-section between the Teeter and the Thrall-Sallyards trends, Greenwood County, Kansas. This section is along the southeast margin of the Teeter trend.

not show any sand at all. The colors of the shale are light gray, dark gray, and, in a few places, black. Most of the black shales are in or near the

sand trends. Lime is not plentiful in the Bartlesville zone. The Bartlesville zone between the trends is like the same zone west of the Teeter trend and east of the Thrall-Sallyards trend. There is no evidence of the presence of a lagoon deposit.

If the Teeter trend is the result of a shore-line process, a line *C C C* (Fig. 7) drawn through the average base of the sand deposit in its original position, should be horizontal, or nearly so. The reconstructed cross-section (Fig. 7) shows the sand deposit in its original position.

Along the regional strike from the NE. corner of Sec. 2 to the SW. corner of Sec. 21, T. 23 S., R. 9 E., the average mass of the Bartlesville sand (allowances made for structural displacement) was deposited on a gradient of less than 7 feet to the mile. The exact gradient probably was between 4 and 5 feet to the mile.

The situation at the Seeley pool, Sec. 5, T. 23 S., R. 10 E., is interpreted by some as a cross-trend and by others as the work of tidal currents cutting through a beach. The situation obviously is not the result of crossed shore lines.

That the crossing of the two trends is the result of tidal currents cutting through a beach cannot be substantiated by the evidence. A careful examination of the data will show that (*a*) the Harris branch of one slope, and the Ellis branch of a different slope, come to grade with the Thrall-Sallyards trend at the point of intersection; (*b*) the restricted sand pattern of the Harris branch does not show a branching into a lagoon, nor does the restricted sand pattern of the Ellis branch show a truncation toward the sea, which are normal features of a tidal delta; and (*c*) there is no thinning of the sands at the point of intersection, and the erratic distribution of sand textures, characteristic of the trends, is present where the sand trends cross. There is no distribution of sand here that would meet the requirements of a tidal delta.

From our examination of the data it seems that the evidence is overwhelmingly against an interpretation of the Golden Lanes as being the result of shore-line processes. We are confronted with the necessity of seeking elsewhere for the cause of the sand deposits. The work of oceans does not satisfactorily explain these long, narrow streaks of sand whose margins are simple, whose cross-sections are complex, and whose features little resemble the forms normal to shore-line development.

EXAMINATION OF EVIDENCE BEARING ON STREAMLINE THEORY

It is obvious that water played a part in the deposition of the sands in the Golden Lanes. We have given reasons for thinking that the sands

were not deposited through the agency of ocean waves, tides, or currents; also reasons for looking to the work of streams as the one remaining possible source of the sand deposits. The valley-flat phase of the fluvial environment, as described by Twenhofel,[1] is believed to correspond closely with conditions under which the sands of the Golden Lanes were deposited.

In the valley-flat environment, according to Twenhofel:

> On the flood plain are deposits made in stream floods, flood-plain lakes and swamps, and under certain climatic conditions there may be dune and other wind deposits. . . . .
>
> Deposits are made on the flood plains during high water. Their nature and colors depend largely on the sources of the sediments, the climatic and topographic conditions at the sources, the climatic conditions over the flood plain, the extent of transportation, and extent and depth of water on the flood plain during each year. On flood plains having an abundance of vegetation, ... the sediments [will be] given gray and perhaps dark colors. On dry flood plains the sediments may be further oxidized, leading to greater intensity of the colors of oxidation. . . . . Some [deposits] are organic and some may arise from chemical reactions caused by the mingling of waters of different tributaries. . . . .
>
> Channel deposits consist of gravels, sands, silts, and clays. . . . . All deposits are lenticularly bedded; more or less extensively cross-laminated. . . . . Sections through channel deposits show lenticular and cut-and-fill bedding. . . . . The channel deposits of a stream migrating over its flood plain are laid down on an eroded surface underlain by flood-plain, channel, lake, and swamp deposits. The channel deposits in turn may become overlain by others similar to those on which they rest.
>
> The flood-plain deposits are mainly silts and clays. Sands are common and gravels are occasional. . . . . The deposits also contain considerable content of soluble matter precipitated from solution of evaporation of water contained in the sediments. In semi-arid regions calcium carbonate, calcium sulphate, and other salts precipitated from evaporating water may be so large as to constitute important parts of the sediments. Calcareous deposits due to evaporation, algal growths, etc., are made in some flood-plain lakes in sufficient quantities to constitute beds of limestone. . . . . The major portions of the organic remains are destroyed before burial.

The textures of the sands in the Golden Lanes range from very fine to coarse, but no conglomerates or gravels have yet been found. Large angular fragmental material is absent. Stratification of textures is fairly uniform, although beds of coarse, medium, and fine sands are interbedded in an irregular manner. It is quite common to find a bed of coarse sand in contact with a bed of fine or medium sand.

[1] W. H. Twenhofel, *Treatise on Sedimentation*, pp. 563–69.

As all streams are more or less crooked, their courses show a meandering pattern. As a stream meanders over its flood plain the line of greatest water velocity impinges alternately on opposite banks, giving rise to a succession of reverse curves[1] of varying amplitude. These reverse curves, together with the straight reaches between the curves, constitute the normal course of a meandering stream.

As the stream works back and forth over its floor its valley is widened. This widened valley also meanders in a series of reverse curves, depending upon the topography over which it passes. The *internal* reverse curves of the river channel, caused by the influence of variable velocity in running water, are more numerous and of smaller amplitude than the *marginal* reverse curves in the course of the river valley, which are primarily due to the influence of topography.

The pattern of the Golden Lanes (Fig. 3) shows very clearly the marginal reverse curves of a meandering river valley.

Streams, because of varying current velocity, consist of alternating deeps and shoals,[2] the deeps at the convex sides, the shoals where the currents cross to the opposite side. During floods the deeps are eroded, the shoals or bars are built up. As the flood subsides the deeps are filled and the shoals are eroded. As the shoals are scoured, finer materials in the upper portion are removed, while the coarser are left. During erosion of the deeps finer materials are removed and coarser materials are left. During low water the deeps are receiving fine material which comes to rest on the coarser material left by previous scouring.

A study of a model of T. 23 S., R. 9 E., shows that in the Teeter trend there is a relationship between some of the low, thick sands and what seem to be internal reverse curves. Evidently the low position of the sand is the result of scouring, while the thickness is effected by subsequent filling. Throughout the trend, layers of coarse, medium, and fine sands occur at random. The complex and irregular bottom of the sand deposits can be accounted for by the scour-and-fill action of streams.

The model also shows the sharp limits of the sands at the margins of the trend. Many wells show from 10 to 50 feet of sand within a location of wells without sand. In several wells a sand thickness of more than 100 feet has been observed next to a well with the sand absent. This occurs on both margins of the sand deposits, and to a large extent is responsible for the regularity and smoothness of the sand margins. Evidently this condition is the result of water running in a channel.

[1] First called to the author's attention in conversation with John L. Rich.

[2] W. H. Twenhofel, *Treatise on Sedimentation*, pp. 28–29.

The occurrences of pronounced breaks in the sand at the margins of the deposits are surprisingly few. Although the sand from producing wells drills up and washes out clean, undoubtedly the sand is interbedded with very thin laminations of shale,[1] which disappear in the process of drilling

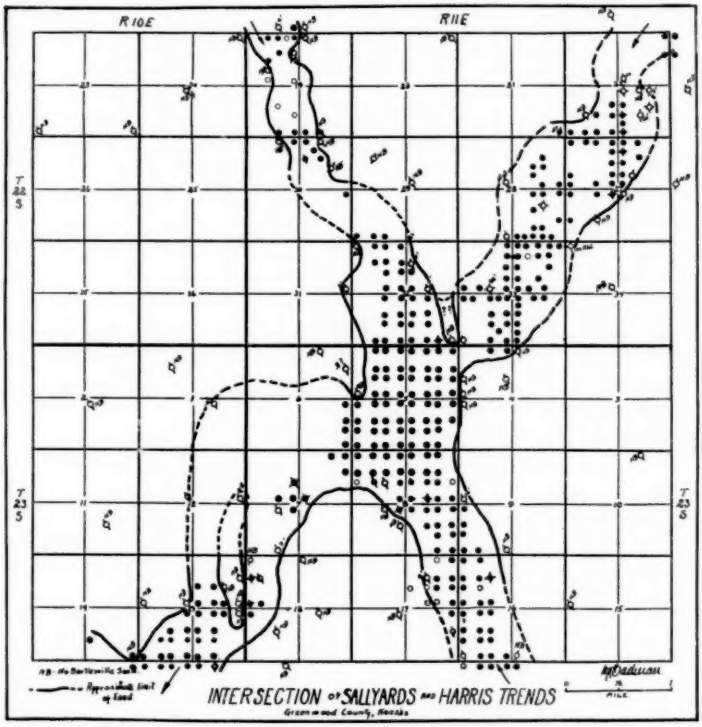


FIG. 8.—Intersection of the Thrall-Sallyards and the Harris-Ellis trends, at the Seeley pool, Greenwood County, Kansas.

and washing the sample. The few pronounced breaks that have been found in the sand are inside, as well as at the margins, of the deposits.

The occurrence of clean sand without pronounced breaks is common in streams whose sands have been transported long distances. The little

[1] Large pieces of sand rock obtained after some shots have shown the thin laminations. In many wells production is found in the lower portion of a thick sand body, evidently held down by a thin lamination of shale.

shale sediment that is deposited after floods is ground up by the sands rolling along the stream bottom, the fine particles of shale passing off in suspension. The sands in the valley of Arkansas River at Wichita, Kansas, evidently have been cleaned in this manner.

It is not a matter of coincidence that the angles between the trend branches and the main trends—where less than 90°—all point in the same

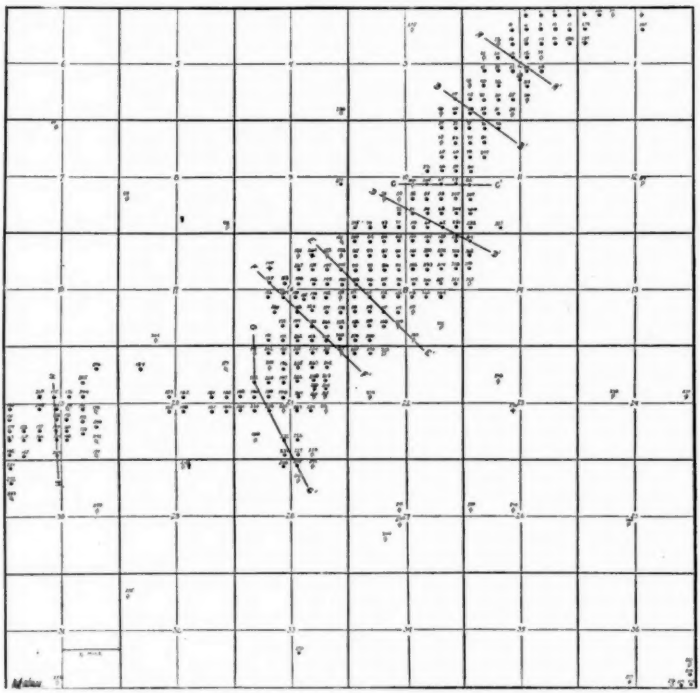


FIG. 9.—Production and township well numbers, T. 23 S., R. 9 E., Greenwood County, Kansas. Location of cross-sections shown in Figure 4.

direction in relation to the main trends. A glance at Figure 3 shows that the angles point "downstream," which is toward the west side of the county.

The Seeley crossing (Fig. 8) is undoubtedly the result of two branch streams entering a main stream at a common point. The Harris branch, flowing southeast on a certain gradient, and the Ellis branch, flowing

northwest on a different gradient, come to grade at the point where the two branches intersect the main stream which flowed southwest. The area of no sand in the SE. $\frac{1}{4}$ of Sec. 12 and the NE. $\frac{1}{4}$ of Sec. 13, T. 23 S., R. 10 E., is an island in the main Thrall-Sallyards trend.

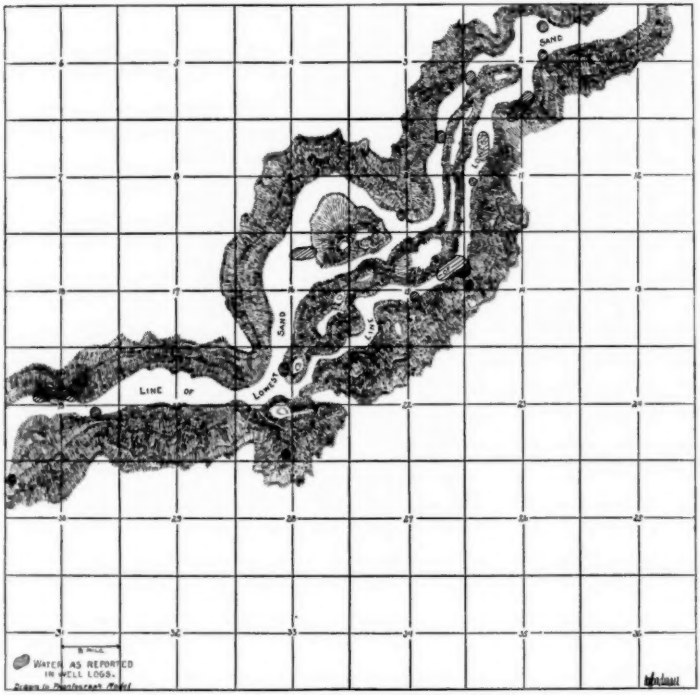


FIG. 10.—Sketch showing the basement of the Bartlesville sand, T. 23 S., R. 9 E., Greenwood County, Kansas. Notice how water, as reported in well logs, follows the line of lowest sand. (Drawn to phantograph model.)

Limestone beds in contact with the Bartlesville sand evidently are the result of evaporation of calcium carbonate in solution, possibly aided by precipitation through algal growth. The limes are very spotty and limited in distribution, and are from 5 to 10 feet thick.

The top of the Bartlesville sand (Plate 8) suggests the presence of sand dunes on a river-valley flat.

The map of the basement of the Bartlesville sand (Fig. 10), drawn

from a model, shows that the sands of the Teeter trend were deposited in a groove scoured in a valley floor by a stream, and not built up from one side by the action of oceanic waves and currents working on a shore line.

The preponderance of evidence points to the sand deposits of the Golden Lanes as being the result of stream deposition in a valley-flat environment. In the Bartlesville sand of the Golden Lanes we have the remains of a great stream system which drained a great valley east of the Nemaha Mountains. This stream flowed in a general southwest direction, where it eventually emptied into a larger stream which drained a great valley west of the mountains.

For the valley east of the mountains the author suggests the name Nemaha Valley; for the Thrall-Sallyards trend, the name Nemaha River, and for the Teeter trend, the West Branch of Nemaha River.

STRUCTURE AND THE GOLDEN LANES

The data may now be examined for any relationship between the structural geology and the deposits of the Golden Lanes.

EARLY HISTORY

The developmental history of T. 23 S., R. 9 E., which is typical of the development of the Golden Lanes, is, briefly, as follows:

1. The first wells drilled in the township were located according to orthodox geological theory; they were on top of the structural highs. They were high and dry.

2. In further prospecting for oil, the first wells to find oil in commercial quantities were down off the structural highs, in north and northwest directions.[1] This led to locations being made according to the following empirical rule: Locate wells for oil west and southwest of structural highs. This rule was followed for several years, until

3. Further drilling invalidated the empirical rule, and drilling in the trends became the common practice.

A comparison of the top of the Kansas City formation (Plate 7) with the top of the Bartlesville sand (Plate 8) shows the following important features:

1. In some places a structural feature in the top of the Bartlesville sand is reflected by a feature of the same type in the top of the Kansas City formation. In most places this condition is not found. Domes over saddles, anticlines over synclines, and noses over domes are the complex rule. The surface of the Kansas City formation does not portray the surface of the Bartlesville sand to any practical or dependable degree.

[1] Early drilling at Sallyards found paying wells west of the structural highs.

2. The Bartlesville sand trend passes over the main structural feature (anticline in the Kansas City formation, with northwest axis, in the center of the township) without any deflection. The sand was deposited before the structural feature was created. When covered, the position and main features of the sand deposit were fixed.

Comparison of production maps (Fig. 9), the top of the Kansas City formation (Plate 7), and the top of the Bartlesville sand (Plate 8) shows that producing oil wells are found on anticlines, synclines, domes, noses pointing in any direction, saddles, and on any side of a structural feature in both the Kansas City formation and the Bartlesville sand, provided the wells are located *in the sand trends*. No production will be found in any kind of a structure where the wells are located out of the trends. Production does not correspond closely to structure in the Golden Lanes.

The list of structures in which oil is found is an imposing one, but, owing to a lack of consistency in production conforming to structure, such a list is of no practical value as an index to possible production in undeveloped territory.

"MISSISSIPPI LIME" AND THE GOLDEN LANES

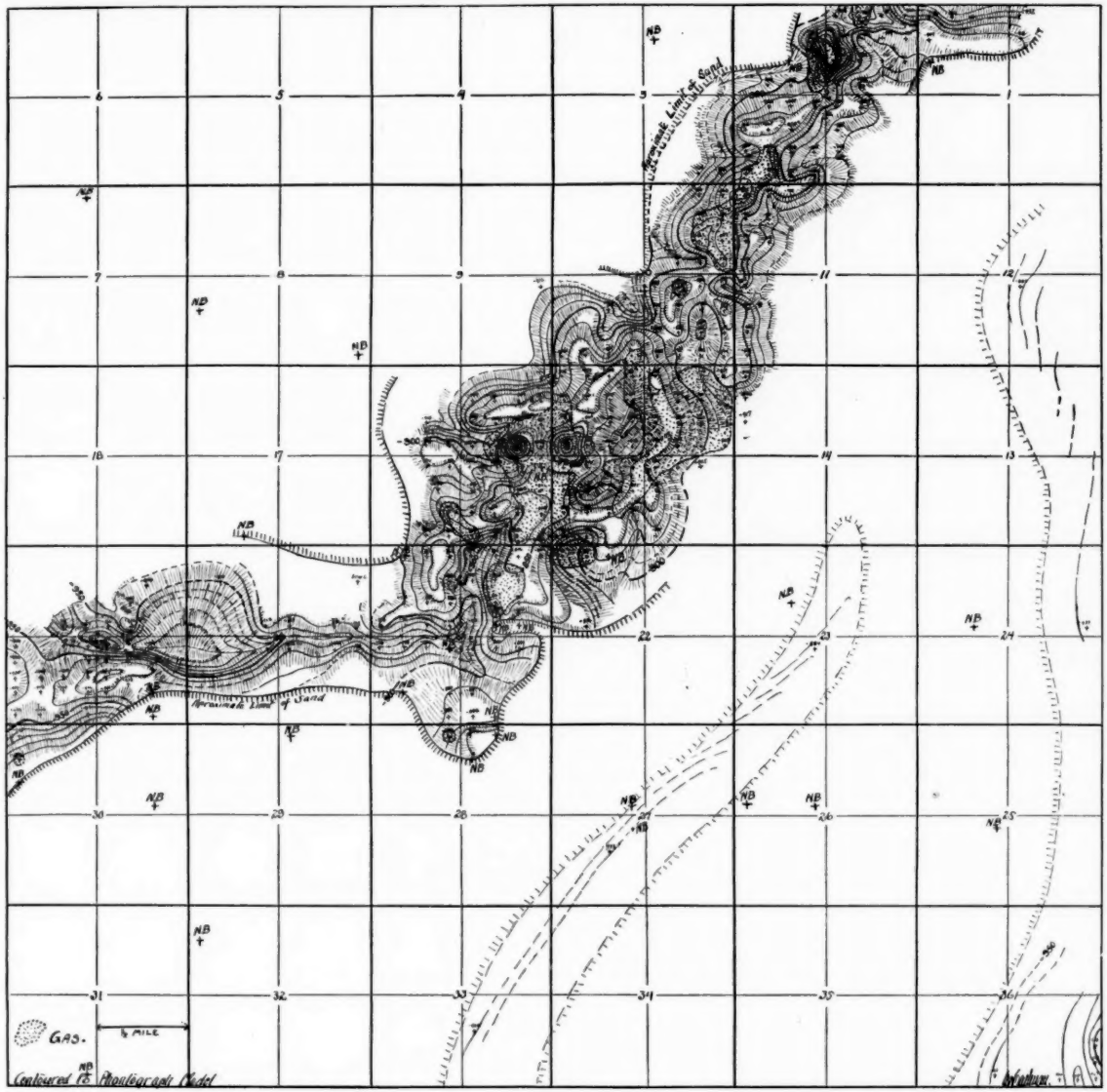
Most wells drilled in the Golden Lanes never reached the top of the "Mississippi lime" because production was found at shallower depths. However, the dry holes in the trends and outside the trends usually were carried to the top of the "Mississippi lime" or beyond, and this class of wells has furnished the data on the top of the lime.

Much work has been done in mapping the surface of the lime, and interest in this work has always been sustained by the belief that there is a relationship between the "Mississippi lime" highs and the deposition of the Bartlesville sand. It is held by some that deposits of Bartlesville sand should be found in the low points of the lime topography—an idea worthy of much consideration until we have an opportunity to subject the idea or belief to a critical test. Such an opportunity presents itself in at least two important places:

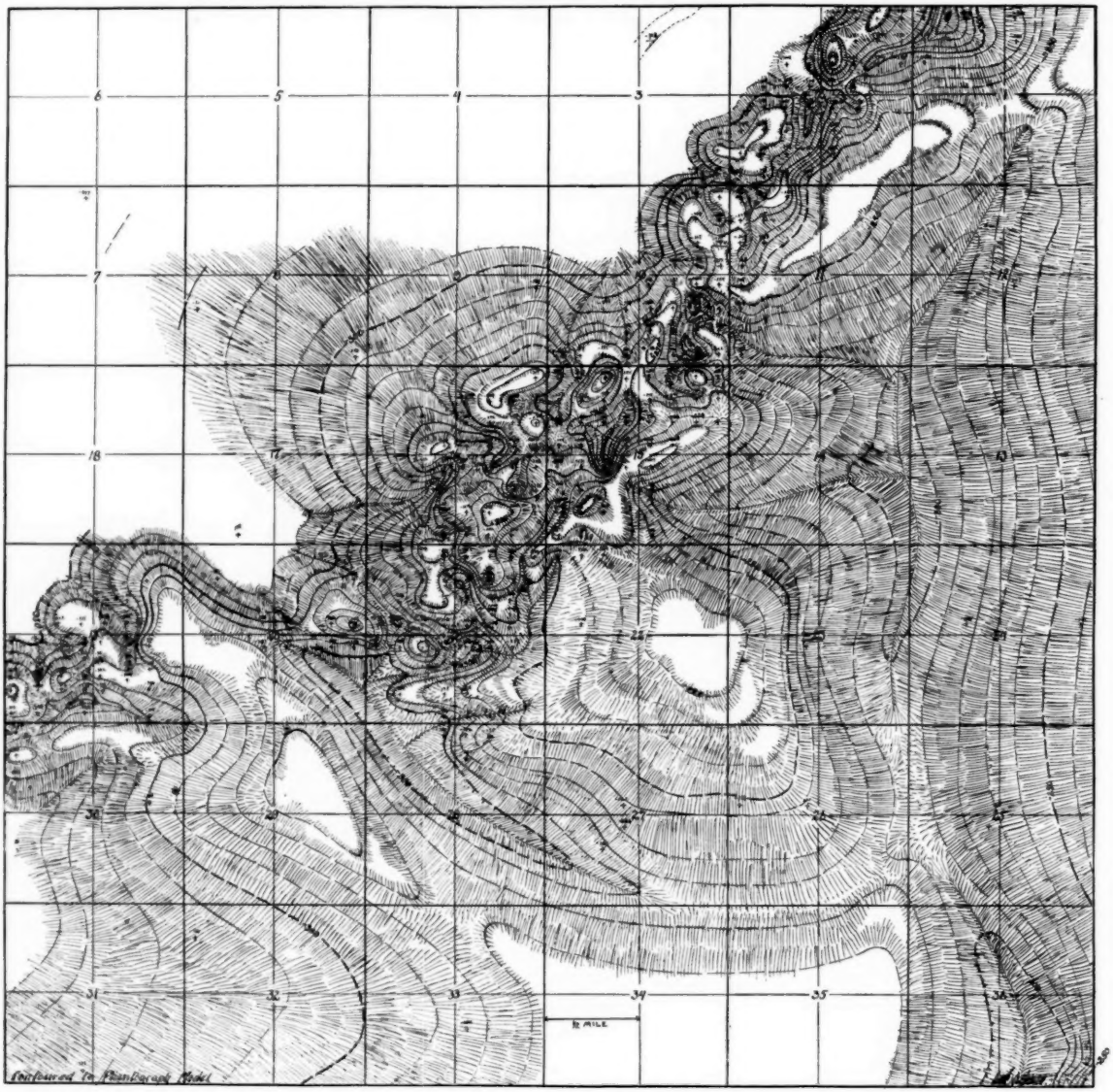
1. At the Keighley pool the "Mississippi lime" is so high that the Bartlesville sand, in places, is resting upon the lime; yet the axis of the sand trend passes over the axis of a nose in the "Mississippi lime" almost at a right angle, without deflection of the sand trend.

2. At the Drumm-Bitler pool, with the lime as high as at Keighley, the sand continues on its course irrespective of the structural feature in the lime below.

Though so few examples do not necessarily invalidate the belief or



Subsurface map showing the top of the Kansas City formation, T. 23 S., R. 9 E., Greenwood County, Kansas. Contour interval, 10 feet. Datum, sea-level. (Contoured to phantograph model.)



Subsurface map showing the top of the Bartlesville sand, T. 23 S., R. 9 E., Greenwood County, Kansas. Contour interval, 10 feet. Datum, sea-level. (Contoured to phantograph model.)

idea, they do warrant our not attaching too great importance to the idea that the high points in the "Mississippi lime" surface have controlled the deposition of the Bartlesville sand.

FLUID ZONES

The fluid in the sands of the Golden Lanes may be divided into three zones, as follows:

1. *The all oil-gas zone.*—In this zone oil and gas are the predominating fluids; water is found only in low places in the sand or in lenticular sheets between layers of oil. The water in this zone is easily handled and exhausted.

2. *The oil-gas and water zone.*—In this zone there is an increase in the amount of water present, but it still is limited to amounts that can be readily handled. This zone grades into

3. *The all-water zone*, in which nothing but water is found in the sand.

This zoning of fluids evidently is due to restricted readjustment of the fluids. When the area of the Golden Lanes was tilted into a regional monocline the oil, gas, and water were unable to readjust themselves up and down the regional dip, but were compelled to readjust themselves *along* the sand trends.

SAND MAPPING

Although we can expect little dependable aid from structural geology in working with the sand trends, we can, through subsurface work, map the sands, and in this way find the sand pattern, which is the key to the solution of the problem. "Map the sand to get into it, and study the sand to stay in it" is a very good rule in working with the sand trends.

FUTURE OF THE GOLDEN LANES

The future of the Golden Lanes depends upon three factors:

1. Closing the gaps in the present main trends and branches. Many present gaps, where not in the all-water zone, have good prospects for production.

2. Extension of the present main trends and branches, and the discovery of new branches. The present Golden Lanes are but a small part of a great system whose limits have not been found. New branches in the present area, and branches in the extended areas, are yet to be found.

3. The Golden Lanes, because of their good sands, their reasonable depths, and because of the *restricted lateral limits* (narrowness) of the

sands, present an opportunity of the greatest importance to those who are interested in the reclamation of oil by the injection of gas, air, or water into the sands.

CONCLUSIONS

From this study of the Golden Lanes of Greenwood County, Kansas, we conclude that (1) The Bartlesville sand deposits of the Golden Lanes are due to the work of streams in a valley-flat environment, and are not the result of oceanic waves and currents working on a shore line. (2) Structural geology is of no value in indicating the presence of the trends, or the best prospects for production in the trends, and (3) the present Golden Lanes are but a part of a much greater system whose details and limits are yet to be found.

GEOLOGY OF EASTERN HIDALGO AND ADJACENT PARTS OF VERA CRUZ, MEXICO[1]

R. H. PALMER[2]
Seattle, Washington

ABSTRACT

The area lies in the eastern part of the Anahuac Desert Plateau and in the Gulf Coastal Plain and the deep canyon-cut area that lies between them. Volcanic plugs are prominent features of the Gulf Coastal Plain. The column consists of Lias, Cretaceous, Tertiary, and Quaternary formations. The eastern edge of the plateau is cut by pre-Tertiary, Tertiary, and Quaternary intrusions. There are extrusive Tertiary and Quaternary flows. The main structures are the Hidalgo anticline near the edge of the plateau and the South Field anticline near the Gulf Coast. Between the two is a broad low valley. It is probable that the petroleum of the South Field originated in the Lias and migrated upward through fractures to the top of the Tamasopo.

LOCATION, SIZE, TRANSPORTATION

The area discussed includes the eastern part of Hidalgo and generally the contiguous part of Vera Cruz, extending thence more or less northeasterly to the Gulf Coast at about the twenty-first parallel of latitude (Fig. 1).

The area extends northeast and southwest and is about 90 miles (145 kilometers) long. The width is approximately 50 miles (80 kilometers).

Access to the western part of the area is by rail from Mexico City to Apulco, thence by auto or animal-drawn stage, depending upon the weather, to Zacualtipan. The stage does not run to Huayacocotla, which is a point of geological importance. This town, however, is but 5 kilometers from Viboras, which is located on the stage line.

At Zacualtipan the road ends and transportation by pack animals only is available. Numerous trails form a network over the country and afford access to any desired point. There are small towns everywhere where food and sleeping accommodations may be secured.

The eastern part of the area is much more accessible. Auto and water transportation from Tuxpan may be had to the southern end of the South Field. The oil companies have constructed good roads that run the entire

[1] Presented before the Association at the New York meeting, November 17, 1926. Manuscript received by the editor June, 1927.

[2] 1825 Third Avenue W., Apt. B, Seattle. Formerly chief stratigrapher and paleontologist of the Instituto Geologico de Mexico.

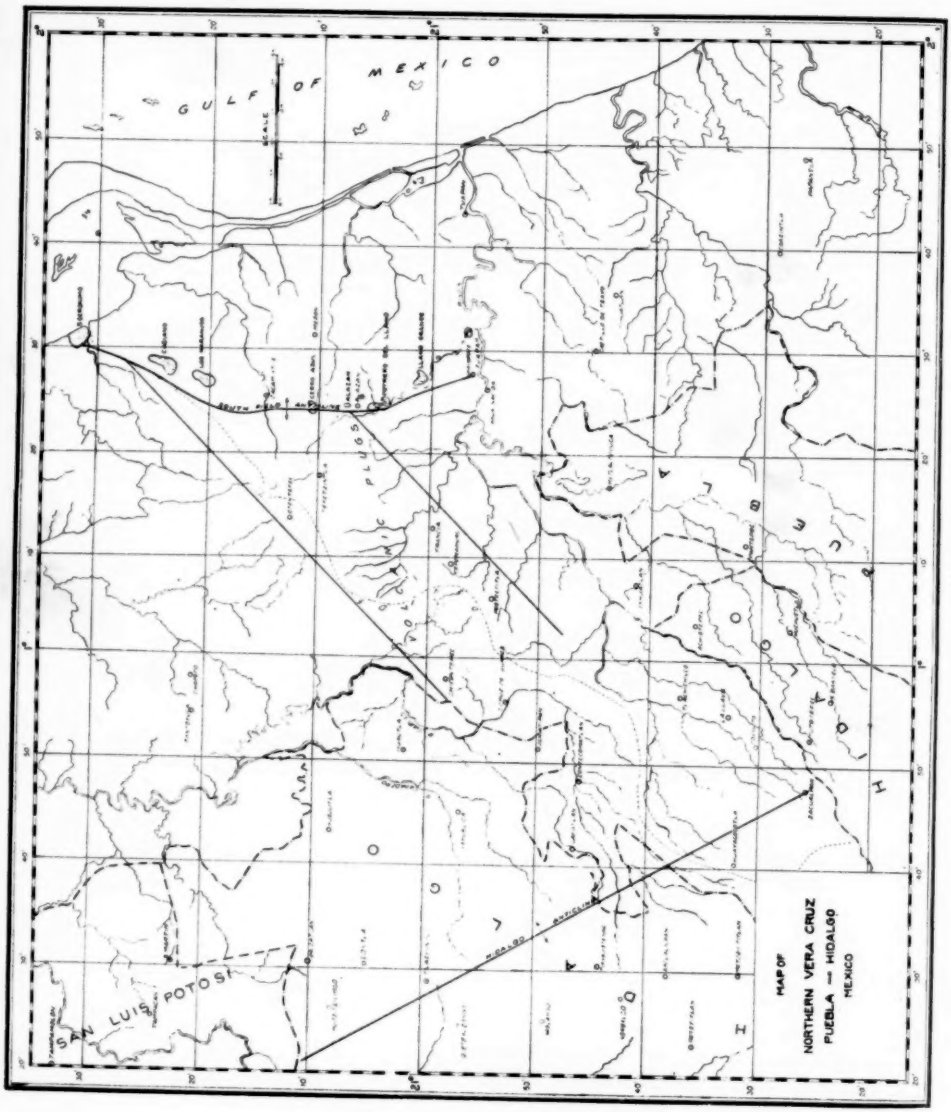

GULF OF MEXICO
SCALE
SAN LUIS POTOSI
MAP OF
NORTHERN VERA CRUZ
PUEBLA — HIDALGO
MEXICO

FIG. 1

length of the South Field from Chapopote to San Geronimo, 45 miles (72 kilometers) to the north. There are branch roads that run to the east and west for several kilometers.

Between the South Field and eastern Hidalgo the only means of transportation is by pack animal. However, the trails are very good. During the dry season autos have occasionally been driven from the coast to Ixhuatlan and Chicontepec, which are situated in the foothills of the Sierra Madre.

TOPOGRAPHY

The area lies in two topographic provinces: the Anahuac Desert Plateau and the Gulf Coastal Plain. The relationship of the two may be visualized as two plains separated from each other by a steeply inclined slope. The former has an elevation of about 7,000 feet (2,150 meters). The latter, the Gulf Coastal Plain, has an altitude of about 1,500 feet along its western edge. The slope or belt connecting the two provinces has a strike of approximately N. 20° W. It is several miles wide and is deeply incised by drainage channels.

THE ANAHUAC DESERT PLATEAU

The Anahuac Desert Plateau, or the Mexican Highland, as it is also termed, is characterized by a series of low ridges with intervening basins or "bolsons." The topography is here and there broken by an outstanding peak.

Along the eastern edge of the plateau rather extensive volcanic activity has covered the surface with a thick mantle of tuff, basalts, and a small amount of rhyolite. The surface of this part of the highland presents a gently rolling topography broken by low hills, some of which are the remnants of old volcanic cones. So unaccentuated is this old topography that at a distance of 10 or 15 miles the surface appears to be a level plain.

There is an old topographic level about 1,000 feet (300 meters) below the highland proper. Numerous remnants of this are seen along the eastern edge of the highland. These remnants are for the most part confined to the upper part of the larger gorges or canyons, where they form terraces. These more-or-less level areas are utilized by the natives for their cultivated fields. Here also many towns are located, for example, Tianguistengo and Zucualpam.

The streams, rejuvenated by a late elevation, have cut deep canyons through this old topography and have totally obliterated it in their lower courses.

Erosion has greatly altered the eastern border of the highland by

cutting these deep canyons. Two of them are typical. The canyon of the Metztitlan at Los Venados is 1,750 feet (540 meters) deep. Chiflon River at Huayacocotla is 3,300 feet (1,000 meters) below the highland.

It is, however, on the extreme eastern edge of the highland that the work of erosion has most profoundly affected the topography. Through the operation of this force the highland has retreated to the west about 20 miles (35 kilometers), leaving as evidence of its former presence long

FIG. 2.—Cerro-Lontla, Hidalgo. Elevation 4,500 feet. This is part of the highland that has been isolated by erosion. About 1,100 feet of basalt and agglomerate cap the Papagallos shales. The latter form the sloping approach.

erosional ridges between the rivers that head in the highland. These ridges slope gradually to the east, where they are eventually lost in the Gulf Coastal Plain.

In the upper courses of the rivers the canyons exist merely as deep cuts in the highland. Farther toward the eastern border, head erosion of the tributaries of neighboring streams has reduced the intervening part of the table-land to a narrow ridge with here and there a detached mesa (Fig. 2). Still farther eastward these mesas entirely disappear, leaving only the undulating ridge. For about 12 miles (20 kilometers) westward from the former eastern edge of the gorge-cut plateau there is scarcely a

remnant of the old level. The result is that the slope between the Anahuac Desert Plateau and the Gulf Coastal Plain presents topographically only a series of steep parallel ridges with intervening deep canyons. These features of the transitional zone slowly change to the east. The canyons become wider and the ridges lower until they disappear and the two areas merge together in the Gulf Coastal Plain.

THE GULF COASTAL PLAIN

This area, as the name indicates, is the low plain that borders the Gulf of Mexico from Tabasco north to the international boundary and thence east to Florida. The part under discussion is a strip across this plain about 30 miles (50 kilometers) wide and at right angles to its general course.

On the whole it presents a flat plain with a low inclination to the east, broken here and there by low ridges, a few volcanic plugs, and low rounded hills on the east. Along the western edge there is an old level that has an elevation of about 2,500 feet (800 meters). This, like the plateau proper, has been deeply incised by the rivers, and in the vicinity of Ixhuatlan reduced to ridges. Here the head erosion of the stream laterals has lowered the crests of the ridges to 700 feet (215 meters). Among the prominent towns located on this level are Huautla and Yahualica.

This old level rapidly drops to the low flat country that has an elevation of about 150 feet (45 meters). This flat area is about parallel to the general features or the main structures. It is included between lines running about N. 20° W. drawn between the small towns of Francia in the eastern part of the district of Chicontepec and Tepetzintla in the district of Tuxpan. Its geological features will be discussed later.

West of the town of Chicontepec another low level has an elevation about 200 feet (60 meters) higher than the drainage channels. This appears both as flat areas and as the crests of low ridges. It seems to represent areas that were inclosed by surrounding elevations during a period of late crustal movements and were subsequently tapped and are now being incised by the head erosion of the drainage.

There are, therefore, four old incised levels: the Anahuac Desert Plateau proper, at an elevation of 7,000 feet (2,100 meters), one at 6,000 feet (1,800 meters), one at 2,500 feet (800 meters), and one at 200 feet (60 meters). The second and third are sloping surfaces and the figures given represent the highest or western edges.

East of Tepetzintla, on the Coastal Plain, low hills and a more rolling topography occur. The terrain here has an elevation of about 1,600 feet

(500 meters), with a low eastward inclination that brings it down to sea-level near the coast.

Volcanic plugs.—In the Coastal Plain there are two areas, more or less clearly defined, where volcanic plugs form very prominent topographic features of the landscape.

The first and more prominent area is included between a line drawn through Chicontepec N. 50° E. toward the coast and another drawn parallel to this 15 miles (25 kilometers) south. This area is marked on the southwestern end by Cerro Postectitla, and on its northeastern end by

FIG. 3.—Cerro-Postectitla, near Chicontepec, Vera Cruz. Elevation 2,500 feet. Highest of the volcanic plugs.

Sierra Otontepec. Between these two mountains are about twenty smaller plugs ranging in height from a few feet to 1,200 feet or more. The largest plug is Cerro Postectitla (Fig. 3), which rises 2,500 feet (800 meters). Sierra Otontepec is an irregular range of hills about 3,300 feet high that extends northeast and southwest. It represents old intrusions and remnants of flows.

The larger plugs are very steep and have the appearance of large teeth. The inclination of their sides is as high as 70 degrees (Fig. 4). The smaller plugs are simply rounded knolls. This general area forms the divide between the Venasco and the lower courses of the Panuco.

The second area of plugs forms a slightly curved line that has a more or less north-south bearing and parallels the area of petroleum production known as the South Field, running practically from San Geronimo to Chapopote in a broad curve that is slightly convex to the west. It is much the narrower of the two, having a width of about 6 miles (10 kilometers)

and a length of about 42 miles (70 kilometers). The two areas form an angle of about 20° with each other.

These plugs are the remnants of volcanic necks that penetrated the formations of the area. Erosion has removed the softer Tertiary down to the present land level while the core of harder basalt, being more resistant, has been left as a steep toothlike spur. The volcanoes were many hundred feet higher than the present plug remnants, as is shown by the fact that the tops of the plugs are hard compact basalt with no traces of the

FIG. 4.—Cerro-Tultepec de Coyote, east of Chicontepec, Vera Cruz. Notice extremely steep left slope.

scoriaceous material that marks the craters of active or recently active volcanoes.

Except for Capadero River, which is in the western part of this general area and flows almost due north, the rivers all parallel the first area of volcanic plugs. Numerous tributaries rise in the plug area, and for the most part flow from it at right angles.

In contrast with the highland, where the water courses occupy deep canyons and where cascades and falls are characteristic, the streams in the Coastal Plain are slow and in places sluggish and have meandering beds that are but a few meters below the general land surface.

STRATIGRAPHY

The geologic column is represented by twelve formations that are for the most part well defined. These range from the Lias to the Pleistocene.

COLUMN (HIDALGO–NORTHERN VERA CRUZ)

System	Series	Formation	Thickness (in Feet)	Lithology and Fauna
Quaternary	Pleistocene	Reynosa	20	Loosely consolidated conglomerate-boulders of chert and limestone from Tamasopo
Tertiary	Miocene	Tuxpan beds	60	Loosely consolidated, buff, marine sandstone with many fossils
		Plug Basalt Loup Fork	750–2,250	Upper part, interbedded fresh tuffs and basalt flows Lower part, interbedded peat beds and basalt flows
	Oligocene	San Rafael	750	Coarse, soft, loosely consolidated, buff sandstone with thick coral beds and thin beds of *Foraminifera* with *Lepidocyclina gigas var. mexicana*
		Hautla Basalt	300	Badly decomposed, greenish-gray
	Eocene	Alazan	3,000	Thinly bedded, fine-grained, blue-gray and buff sandstones and shales, soft. Few, poorly preserved fossils
		Chicontepec	2,000	Bedded sandstones above with bryozoans and swamp flora. Blue shales with *Foraminifera* below
Upper Cretaceous		Papagallos-Mendez	1,200	Soft thinly bedded blue or purplish shales. Thinly bedded sandstone locally. *Foraminifera*
		San Juan-San Felipe	200–300	Thinly bedded gray limestone with beds of green bentonite(?). *Foraminifera*
	Turonian	Tamasopo-Maltrata?	250–1,000	Massive and bedded gray limestone with black chert. Many *Foraminifera*
	Cenomanian	Necoxtla	5,000±	Shales, dark gray, blue-black, and dark greenish-gray weathering red, brown, and yellowish-brown; phyllitic and talcose locally. Contains casts of sponges, corals, crinoids, and *Trigonia*
Jura	Lias		3,000	Black shales weathering brown, with *Arietites*. Intruded conglomerate at base

JURASSIC

Lias.—The Lias or Lower Jurassic is the thickest of the formations in the area. In Hidalgo, where it is exposed by erosion along the crest of an anticline, it has a thickness of 3,000 feet (900 meters). At the base in the canyon of the Rio Mesquite near Huayacocotla, a conglomerate of unknown thickness is exposed. For lack of fossil data the age of this is not definitely known, but its position at the base of the Lias shale permits the tentative assumption that it is the basal conglomerate of the Lias.

The lower beds of the Lias are intruded by an altered andesite which locally altered the shale to a schist and the conglomerate to a quartzite. Subsequent movements have thrust long tongues of this schist into the conglomerate, and vice versa.

Above the conglomerate are the Liassic shales with *Arietites*, *Peri-*

sphinctes, Belemnites giganteus and beds of fossil plants. The age of this formation was first determined by Barcena.[1] Later Aguilera[2] also noted the Lias in this locality. In 1898 Böse[3] published a summary of the Lias of Mexico. Lozano[4] has described the plants found in this formation. The forthcoming bulletin by C. Burkhart on the paleontology and stratigraphy of the Lias of this section is awaited with eagerness by those interested in the geology of this region.

This formation is very thick and extensive. It is found in the states of Oaxaca, Hidalgo, Vera Cruz, Queretero, and Pueblo.[5] It is a black or bluish-black shale and very uniform from the base to the top where examined by the author in the canyon of the Mesquite. This weathers to a brown or yellow, which gives it an entirely different aspect from that which it presents when seen with fresh surfaces. In places it has a fetid odor. In a personal communication Professor Cummins stated that chapopote[6] has been found exuding from it.

In all places where seen the Liassic shales are much sheared. So prevalent is the shearing that only fragments of the fossil content can be procured.

CRETACEOUS

Cenomanian—Necoxtla.—The lowest member of the Cretaceous is what Böse[7] has termed the Necoxtla. He thus describes[8] this formation as found near Necoxtla in Vera Cruz:

> La mayor parte de este division se compone de pizarras arcillosas amarillentas, grises y rojas, con lustre de seda, en las cuales se encuentran con alguna frequencia segregaciones de crystales de pirita. ... Las pizarras contienen en algunas partes mica en poco cantidad; su esquistosa estructura es muy ficil; en la desintegracion las hojas se quiebran en pedazos delgados alagardos en barras. ... Lechos aislados de caliza estan intercalados entre las pizarros y areniscas. ...

[1] *Anales del Museo National de Mexico,* Vol. 1 (1877), p. 285.

[2] "Bosquejo geologico de Mexico," *Inst. Geol. de Mexico, Bol. 4-5-6* (1896), p. 149.

[3] "Über Lias in Mexico," *Zeitschrift der deut. geol. Gesellschaft,* Vol. 50 (1898), p. 168.

[4] *Inst. Geol. de Mexico, Bol. 34* (1916).

[5] Böse, "Über Lias in Mexico," *Zeitschrift der deut. geol. Gesellschaft,* Vol. 50 (1898).

[6] *Chapopote* is the common term used in Mexico to designate the asphalt that accumulates around seeps.

[7] Böse, *Inst. Geol. de Mexico, Bol. 13* (1899), pp. 5, 6; *Bol. 16* (1902), p. 16.

[8] *Ibid., Bol. 13.*

Böse's description of this formation in La Hacienda de Vaqueros in Hidalgo is essentially the same.

To this description may be added a few minor observations made elsewhere. The general aspect as described by Böse is that found on weathered surfaces where reds, browns, and bright colors predominate. Where fresh surfaces are exposed, dark gray, blue-black, dark green, and similar shades are the colors it suggests. Near Nonoalco, Hidalgo, there are large beds where shearing under pressure has resulted in phyllitic or talcose structure which imparts a decidedly talcose feel to the rock.

Wherever found this formation is soft and friable and readily lends itself to erosion, with the result that it forms no cliffs but rather a soft topography wherever it makes up an appreciable part of the landscape.

In the Nonoalco section fair-sized veins of quartz and calcite occur. Like the rest of the formation, these veins also show the effects of shearing. Here it is also intruded by rhyolite.

Wherever Böse has encountered the Necoxtla it has been for the most part unfossiliferous. However, in the Nonoalco area thin beds of shales with sponges, corals, crinoid stems, *Trigonia*, *Glycymeris*, and other smaller lamellibranchiata are common. Unfortunately the remains are casts only, making specific identification and the definite determination of the age impossible.

On the slopes of Agua Frio west of Molango several beds of wad are seen near the upper part of the Necoxtla. These are each several meters thick and resemble marsh or bog deposits.

In the Zucualpam-Tuxpam section this formation is not well exposed (see section). On the western limb of the Hidalgo anticline (see p. 1203) it is intruded and its structure and thickness thereby masked. On the eastern limb the lateral forces of compression that caused the anticline, together with its position with respect to the more competent limestone above, resulted in its being sheared and crimped to such an extent that quantitative data on its thickness cannot be obtained. At Huayacotla, which is located on the axis of the anticline, it is found to lie apparently conformably on the Lias. However, here it is also sheared and there are but 100 meters or so exposed on the western limb of the anticline. The remaining part passes under the mantle of the Tertiary effusives.

In the canyon of the Metztitlan at Los Venados the same formation is seen. It has here the same general aspect as in the other places.

The best available data on this formation were secured in the general vicinity of Nonoalco, which is about 10 kilometers northwest of Zacualtipan. It is probable that nearly the complete section is here shown. The

lowest member is a conglomerate bed which is assumed to be the base, and above the thick series of overlying shales is the Turonian Maltrata (?) limestone. It has a general west dip at this point and there are exposed at least 5,000 feet (1,500 meters). A description of this section, with the exception of the basal conglomerate, would be a mere repetition.

The age of the Necoxtla is not definitely known. From its stratigraphic position Böse[1] was of the opinion that it is Aptian-Urgonian and equivalent to the Trinity series of Texas, and later that it is lower Cenomanian[2] or Aptian.

The Necoxtla clearly lies under the Maltrata limestone, which for reasons given later is ascribed at least in part to the Turonian and the Eagle Ford of Texas.[3] This stratigraphic relationship is seen in several parts of Hidalgo, Vera Cruz, and Jalisco. In Jalisco below the Turonian-Maltrata are found about 30,000 feet (10,000 meters) of shales, sandstones, and conglomerates, together with a few thin beds of limestone. These latter are made up entirely of fossil remains. Wherever encountered, the light-colored shales are seen to lie under the limestone. At the bottom of the series in Jalisco are found *Caprinula*, *Nerinea*, *Schiosia*, *Chronodontia*, corals, and *Orbitolina*, which are lower Cenomanian types. If this formation is correlated with the Necoxtla, which seems proper, Böse is undoubtedly correct in determining it as Cenomanian or lower Cenomanian. In further support of this view, Wittich reports the presence of a similar faunal assemblage in this formation in Hidalgo.[4] However, as collections from this fauna are not available, definite correlation is not possible.

Turonian; Tamasopo in part; Maltrata.—Immediately above the Necoxtla is the Tamasopo[5] limestone (Fig. 8). This appears at Cojolito, 11.5 kilometers northeast of Zucualpam. It is massive in structure, bluish-gray in color, and contains many nodules of black chert. These last range from 5 to 20 centimeters in length, are oval in cross-section, and are

[1] *Inst. Geol. de Mexico, Bol. 13* (1899), p. 16.

[2] *Ibid., Bol. 16* (1902), p. 16.

[3] This correlation is open to question.

[4] Wittich, *Mem. de la Soc. Cien. Antonio Alzate*, Vol. 38 (1920), p. 412.

[5] The term Tamasopo is applied in a general sense to the extensive limestone that underlies the South Field and appears at the surface in the mountains in eastern Hidalgo and western Vera Cruz. It may be either the Tamaulipas or the underlying El Abra or it may include both. According to Belt (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, p. 138) and Trager (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, p. 673), the limestone at the producing horizon of the South Field is the El Abra. The presence of rudistids in the outcrops in eastern Hidalgo and at El Abra and in material blown from wells in the South Field lend support to this view.

irregularly elongated. For the most part they are parallel, but in places branches cross the bedding planes of the limestone. They also occur in thin lenticular beds in the limestone. The origin of these chert bodies is not clear. They have been attributed to aggregations of sponge spicules, but thin sections fail to reveal any trace of such structures. They seem to have been formed contemporaneously with the lime matrix, as is evidenced by the presence of the same Foraminifera in both the chert and the limestone.

Böse has observed the presence of this chert in the Maltrata.[1]

DeGolyer, speaking of the Tamasopo in the Furbero area,[2] states that it "consists of hard gray, pure, compact porcelain-like limestone in layers

FIG. 5.—Bedded and folded Tamosopa near Lontla, Hidalgo

of less than a foot thick and is characterized in its upper part by the occurrence of an abundance of black to dark gray and green chert nodules interbedded with the limestone. . . . . The thickness of the formation in this region is unknown but probably is from 6,000 to 8,000 feet." This description is also applicable to the Tamasopo at Cojolito. The black chert feature is rather extensive. It is found in the Tamasopo at Tlanchinol, Hidalgo, and in the north near Monterrey. It is usually considered as characteristic of the upper part of the Tamasopo. However, for correlation purposes it is of doubtful value for reasons to be pointed out later.

At Cojolito the Tamasopo is only 70 meters thick. Here it is greatly

[1] Böse, *Inst. Geologico de Mexico, Bol. 13* (1899), p. 6; *Bol. 16* (1902), p. 16.

[2] De Golyer, *Trans. Amer. Inst. Mining Engineers*, Vol. 52 (1916).

fractured and faulted. Farther north, in the general vicinity of Tlanchinol, it becomes much thicker. Here it is likewise folded, sheared, and faulted to such an extent that accurate measurement of its thickness is impossible (Figs. 5 and 8). It is probably, however, not less than 1,000 feet (300 meters) thick. The lower part is a dark gray, passing to a light gray above, and near the top is the black chert.

The black chert near Tlanchinol is 300 meters above the base of the Tamasopo, although at Cojolito it is but 50; hence, for more than general correlation purposes it is useless.[1] Mention of boulders of this chert in younger formations will be made later.

Still farther north the Tamasopo becomes much thicker. Tentatively, a thickness of 4,000 feet (1,200 meters) has been ascribed to it in the vicinity of Victoria, and Hill[2] and DeGolyer[3] have given it as much as 20,000 feet. DeGolyer states that it is "probably 6,000 to 8,000 feet in the Furbero section."[4]

The Tamasopo is a persistent formation and of very broad extent. It is found on both sides of the Mexican highland. On the western side it appears in Colima, Jalisco, Oaxaca, Guerrero, and Morelos. On the eastern slope it occurs in Vera Cruz, Puebla, Mexico, Hidalgo, Queretero, San Luis Potosi, Tamaulipas, and very probably in Nuevo Leon. More extensive field investigation would probably reveal it in all the states located on the western edge of the Mexican highland and probably in the northern part of the Republic.

It is of interest to note that in Morelos, Colima, and Jalisco on the western edge and in Puebla and Hidalgo on the eastern edge of the highland this Turonian limestone is the first of the sediments that appears on the surface stratigraphically under the extrusive mantle that for the most part covers the central mesa. Thus the younger Cretaceous and the Tertiary sediments were not laid down in these parts or else were eroded prior to the deposition of the Tertiary extrusives.

For the most part the Tamasopo limestone is massive in structure and forms bold high cliffs. This feature is seen in the bold topography just east of Esperanza on the Mexican Railroad between Mexico City and

[1] Belt (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, p. 139) and Trager (*ibid.*, Vol. 10, p. 673) state that these cherts occur in the Tamaulipas limestone. It is therefore possible that both the El Abra and the Tamaulipas horizons occur in eastern Hidalgo and western Vera Cruz (see footnote 2, p. 1181).

[2] Hill, *Amer. Jour. Science*, 3d series, Vol. 45 (1893), p. 309.

[3] DeGolyer, *Econ. Geol.*, Vol. 10 (1915), p. 653.

[4] DeGolyer, *Amer. Inst. Mining Engineers Bull. 105* (1915), p. 1905.

Vera Cruz, along the canyon followed by the railroad from Cordova to Santa Lucretia, and at several places between San Luis Potosi and Tampico, for example, at Micos, Tamasopo Canyon, and Valles. In Jalisco it forms the steep cliffs at Huescalapa between Guadalajara and Colima, and in part the very spectacular gorge seen just before reaching Colima. This cliff-forming feature seems very general wherever faulting or erosion has exposed any considerable amount of this formation. It is especially marked where erosion has cut through the Tamasopo and into the soft underlying shales of the Necoxtla.

Exceptions to this massive structure are met in places and a definitely bedded local facies is encountered (Fig. 5).

Caves very commonly occurred in the Tamasopo. The renowned caves of Cacajuimilpa in Guerrero are in this limestone. Caves of some magnitude also occur in Colima and San Luis Potosi. Deeply buried caverns are encountered in many places in the Tamasopo in the oil-producing areas of Vera Cruz. Drillers often report a sudden dropping of their bits after this limestone is reached. Many pieces blown out of wells by gas or oil pressure are from the sides of cavities. Other pieces show crustification, or drusy or filled cavities. The significance of these will be discussed later.

Age.—It is possible and also probable that the Tamasopo includes both the Maltrata and Escamela of Böse's Orizaba section. The former he ascribes to the Cenomanian and the latter to the Turonian, and he correlates both with the Comanchian of Texas and with the Cenomanian and Turonian of the European sections.[1]

In the limestone directly above the Necoxtla in Jalisco, Morelos, and Hidalgo, *Radiolites mendozae* Barc. and other species have been found. These are Turonian types. In Jalisco throughout 900 feet of this limestone only Turonian fauna is found. As there is no further information available at present, all that can be stated with definiteness is that the lower part of the Tamasopo is Turonian.

San Felipe (San Juan).—This formation apparently rests conformably on the Tamasopo wherever encountered in the area under discussion. The San Juan type locality is in Nuevo Leon on the west side of Salada River in the San Juan Hills. Dumble[2] states: "Toward the base the limestones are shaly, dark gray in color, and weather gray to whitish. Toward the summit the limestones are of a bluish shade weathering white. The

[1] Böse, *Inst. Geologico de Mexico*, Vol. 13, p. 16.

[2] Dumble, "Tertiary Deposits of Northeastern Mexico," *Proc. Cal. Acad. Science*, 4th series, Vol. 5 (1915), p. 173.

uppermost beds are sandy and weather to a reddish or rusty color. They carry numerous impressions of ammonites, oysters, and *Inocerami*, which are forms referable to the Taylor or Austin horizons of the Texas sections."

The same formation was described by Jeffreys (in a private report) in 1910 as seen near the station of San Felipe west of Tampico, and the name San Felipe was applied. Dumble reports Jeffreys as stating that these beds are transitional between the Tamasopo below and the Mendez above, and that limestone predominates toward the base and shades into blue shales above. The thickness is estimated to be not more than 500 feet.

Huntley[1] describes the San Felipe formation as follows: "This may be described as a transitional series between the Upper Mendez marls and shales and the underlying massive Tamasopo limestone. . . . ." This transitional nature seems to be evidenced by the well logs both in the Panuco and South Field producing areas.

The foregoing descriptions characterize this formation in a general way. Observations made in other localities add a few important details. At La Llave, on Chiflon River, northeast of Zucualpam, there is a fair exposure of the San Felipe. It is seen to be a very regularly bedded limestone with beds ranging in thickness from 10 to 30 centimeters. These are light gray in color and in places carry many Foraminifera. The transitional aspect is not in evidence here. The portion of the section exposed is very uniformly of the bedded series. It is gently undulating with a general strike of about N. 35° W. and a regional dip of about 36° NE.

Interbedded with the limestone are many beds of light green clay-like material ranging from 2 to 10 centimeters in thickness. In the Panuco area are thicker beds of what is probably the same material though altered to a plastic clay that has the general appearance of bentonite. The origin of this material is not wholly clear. It may represent either old deposits of tuff or may be sediments derived from some old basic land mass.

The economic significance of these beds is very great. It is at the base of the San Felipe and the top of the Tamasopo that practically all the oil in the South Field has been found. In other words, it is this clayey mantle that appears to form the capping for the structures where oil has accumulated.

In northern Hidalgo, in the general vicinity of Tlanchinol, there are good exposures of this formation. Here again the transitional aspect is not in evidence. In one locality where a small creek flows diagonally across

[1] Quoted from Dumble, "Geology of the Northern End of the Tampico Embayment Area," *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), p. 130.

the Tamasopo–San Felipe contact, the latter is well defined. The Tamasopo is seen to have great regularity, though considerably folded, and to show little or no shearing. The contact is really the beginning of a shear zone that extends well up into the San Felipe. The latter is irregularly folded. Though the aspect of the two formations here is quite different, there is not necessarily an unconformity between them, the structural differences between them being in the main due to the relative incompetency of the more thinly bedded San Felipe.

The observations of Huntley, Jeffreys, and Dumble relative to the increasing predominance of shale in the upper part of the series is in accordance with the observations made in northern Hidalgo, with the added suggestion that the shale is very hard and resistant.

An aspect of the weathering of the shaly phase in the upper part is worthy of mention as an additional means of identification, though it may be of local application only. Large slabs, where exposed on a low dip, weather in a decidedly mosaic pattern, resembling mud cracks, though the units are in dimensions of a few centimeters only.

The thickness of this formation is very difficult to determine due to its faulted and sheared structure. Jeffreys estimates it as not more than 500 feet (150 meters); Huntley, from 300 to 800 feet (90–250 meters), and J. J. Galloway in a personal communication gives a tentative estimate of 1,500 feet (460 meters). Dumble states that the thickness ranges from 400 to 800 feet. DeGolyer gives the same figures. At La Llave it was impossible to do more than estimate the thickness, which was taken to be about 200 feet. Near Petlacatl in northern Hidalgo a fairly accurate measurement showed 300 feet.

Papagallos—Mendez.—Directly above the San Felipe and apparently conformable upon it rests the Papagallos or Mendez shales. This formation was first studied by Cummins and Dumble in the Papagallos Hills west of Ramones in Nuevo Leon, from which it received its name. In the type locality it is described as "a series of very fine-grained blue or black limy clay shales, weathering brown, yellow, or white, in which we have found no fossils."[1]

Jeffreys describes the same formation at Mendez between Tampico and Ebano as follows:

> This formation consists of a very uniform deposit of gray to blue shales, which, in the higher levels, verge into an indurated clay or semi-marl, with a bolder fracture instead of the fine shaly appearance. . . . . From top to bottom

[1] Dumble, "Tertiary Deposits of Northeastern Mexico," *Proc. Cal. Acad. Science*, 4th series, Vol. 5 (1915), p. 170.

of this Mendez marl there is practically no change in the lithological character, save some irregular beds, varying from two inches to two feet thick, of a sandy limestone.[1]

Huntley gives the following description:

The Mendez marls consist of a very uniform deposit of gray to blue shales and marls. In regions of steep folding, these often show bold jointing near the surface. There is practically no change in their lithological character from top to bottom. They average from 2,000 to 3,500 feet in thickness. In the Huasteca country they are nearer the former thickness. A few irregular beds of sandy limestone are reported in this formation, but they are not persistent. However, there are frequent small quantities of heavy oil immediately below them, although never enough to sustain production of commercial importance.[2]

DeGolyer describes the Mendez as follows:

Grading from the underlying San Felipe beds is a thick series of gray to green shales, marls, and clays, containing rarely thin shaly sandstones and limestones and red shales called the Mendez shale, because of the outcrop near Mendez station, just west of Tampico. . . . . The thickness of this formation at Furbero is approximately, 4,000 feet. No fossils have been found in this region; but a collection made at Alazan. . . . .[3]

He ascribed this formation as well as the San Felipe to the lower Tertiary.

The foregoing notes are partially descriptive of the Papagallos as it appears in eastern Vera Cruz and Tamaulipas. To these a few additions are to be made. North of Tampico, in the vicinity of Manuel, two distinct phases are in evidence. There is a lower gray shale with a few harder beds. This contains many Foraminifera, *Balanocrinus mexicanus*, Stephenson, two species of *Sauvegesia*, *Ostrea*, a few bone fragments, and *Spondylus*. Overlying this is a pink phase with *Tampsia bishopi* Stephenson and also many Foraminifera. Both of these phases are similar except for the very noticeable difference in coloration which is probably due merely to a slight and perhaps local difference in the conditions of sedimentation.

Along the eastern flank of the Sierra Madre Oriental these descriptions do not apply with a great degree of accuracy except for the upper part of the formation. This area represented greater proximity to the source of the materials of the formation. Here the lower part of the formation, as exposed at Lontla, north of Tlanchinol in the state of Hidalgo,

[1] Quoted from Dumble, "Geology of the Northern End of the Tampico Embayment Area," *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), p. 130.

[2] Huntley, *Trans. Amer. Inst. Mining Engineers*, Vol. 52 (1916), p. 304.

[3] DeGolyer, *Trans. Amer. Inst. Mining Engineers*, Vol. 52 (1916), p. 275.

and in that general area, is composed of a rather uniform series of fine limy sandstone and shale beds.

The sandstones range in thickness from a few centimeters up to 15 or more. Fresh unaltered surfaces are bluish-gray. These weather to a dull brown-gray. Intercalated with the sandstone beds are gray and bluish-gray shales, many of which show the presence of much biotite. These shale beds in many places constitute the greater part of the formation. With the exception of a few Foraminifera and casts of worm holes, no fossils were found in this locality. There are at least 1,600 feet (500 meters) of this series exposed. It is probably thicker, as the top was not seen in the vicinity of Lontla.

Farther east, on the eastern limb of the Hidalgo anticline, the upper shaly series occurs and here Dumble's description is applicable.

East of La Llave the Papagallos presents still another phase. The lower sandstone members are missing. The splintery Papagallos shales with a few thin limestone beds rest directly on the San Felipe. The lower part is a bluish-gray and above is a thick series of highly colored shales where browns and rich purples predominate.

Practically everywhere the shale members of the Papagallos have one common feature that is brought out by weathering. This is the structure due to lateral forces that have acted on it. In places this takes a splintery form, but more generally the pressure has formed small ovoid or elliptical bodies a few centimeters in diameter. Weathering causes the roughly concentric layers to fall apart, leaving a kernel of more or less regular form.

The thickness of the Papagallos is very difficult, if not impossible, to determine with any great degree of accuracy, due to several causes. The formation is relatively very incompetent in respect to the underlying San Felipe. At the time of folding it was not buried by sufficient sediments above to confine it with any degree of regularity, with the result that it is badly sheared, folded, and overthrust, and hence telescoped on itself wherever it is exposed at the surface. Another equally potent reason is the inability to locate its contact with the overlying Tertiary Chicontepec into which it grades with no lithological difference. The scarcity of fossils in both formations increases the difficulty. As both the Papagallos and the Chicontepec carry Foraminifera it is hoped that these may furnish the data that will ultimately establish the line between these two formations.

Various estimates have been made of the thickness. Huntley states: "They average 2,000 feet to 3,500 feet." J. J. Galloway gives a tentative

estimate of 1,500 feet (460 meters). The former figures are too large an estimate for the thickness in eastern Hidalgo. The latter is probably within a 15 per cent error for the South Field. Dumble says: "The total thickness in this area (Tuxpan-Tampico Field) of the Papagallos is estimated at 700–1,200 feet." DeGolyer gives an estimate ranging from 2,000 to 4,000 feet without citing the locality.

TERTIARY?

Eocene—Chicontepec.—The Chicontepec in the South Field has been ascribed to the Tertiary on grounds wholly insufficient as far as available published data are concerned. Dumble states: "From the strong resemblance of the Chicontepec beds to those of the Eocene at Ramones, Professor Cummins was inclined to refer them to that horizon."[1] In the same publication, page 133, he writes: "The Eocene deposits of the Tampico Embayment area are quite different from those of the region north of the Tamaulipas range."

From evidence that will be pointed out later it would seem that at least the lower part of this series could well be placed in the Cretaceous.

The Chicontepec is the last sedimentary formation that appears on the eastern flank of the Sierra Madre Oriental, as well as the youngest formation that participated in the folding of the Hidalgo anticline.

The Chicontepec is made up of a thick series of shales below and hard bluish-gray sandstones above. In the upper part of the shales thin sandy lenses appear which become more numerous and larger until they predominate and pass into the hard sandstone beds that form the upper part of the series.

The description of the Papagallos shales given by Dumble is wholly applicable to the Chicontepec shales. From Tutitlan to Orizatlan in northern Hidalgo the trail passes from the Papagallos to the Chicontepec, yet observations in the gully exposures fail to reveal any lithological difference between them, though this seems to be the only criterion thus far employed to distinguish them.

Between Orizatlan and Huitilzilingo, a few kilometers to the west, the thin sandy beds appear which, as previously stated, become more numerous and finally pass into the hard flaggy bluish-gray sandstone in the upper part of the formation.

The sandstones are composed of well-defined beds that range in thick-

[1] Dumble, "Geology of the Northern End of the Tampico Embayment Area," *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), p. 136.

ness from a few centimeters to half a meter or more. This is very uniform in texture. The grains are somewhat rounded and frosted. There are considerable amounts of small feldspar, hornblende, and biotite grains, which give it an arkose or graywacke appearance. The origin of this material seems to have been an old rhyolitic or granitic land mass to the west which was entirely eroded or the remnants covered by the later Tertiary effusives.

The upper part of this sandstone or arkose member contains casts of *Lycopodium* and the sterile filaments of *Equisetum* (Fig. 6) as well as well-defined fragments of monocotyledons and broad-leaved trees, and at the top are beds with small water-worn fragments of pearly shells that resemble *Unio*. The interpretation will be given under the head "Geological History." A few kilometers west of Chicontepec, rather high up in the sandstone, are beds containing oval concretions with a maximum diameter of nearly a meter. These have been noted by Dumble.[1]

FIG. 6.—Casts of equisetum stems from upper sandstone member of the Chicontepec. Paving block from Huejutla, Hidalgo.

A short distance northeast of San Miguel, between Zucualpan and Ixhuatlan, the flaggy Chicontepec sandstone is encountered. No attempt is made to differentiate between the shales of the Papagallos and the Chicontepec. The sandstone closely resembles that farther north, with the exception that it is for the most part more highly folded, and the unimportant details that the individual beds are somewhat thinner, have greater regularity, and have thinly interbedded shales. Folding and faulting (Fig. 7) are much more intense to the south and so prevalent that it is impossible to measure the section with any degree of accuracy worth recording. The sandstone forms practically all the hills and ridges from the vicinity of San Miguel to Ixhuatlan, which is situated on this formation. On the eastern edge of the town it passes under the alluvium and more recent formations and is not encountered farther east except in wells on the western edge of the South Field.

[1] *Ibid.*

In the vicinity of Ixhuatlan the Chicontepec sandstone is marine. This is evidenced by the poorly preserved *Bryozoa* that it contains.

The stratigraphic relationship of the shale and the sandstone members is at variance with the observations of Dumble,[1] who reports as follows:

While the sandstones greatly predominate at the base, they are interbedded with yellow clays and the sands become thinner and the clay bands become thicker higher in the section. Halfway down the mountain the sandstones

FIG. 7.—Folded Chicontepec along trail between Yahualica and Puerta, Hidalgo

carry boulders of concretionary clay ironstone, some of which are as much as two feet in diameter. Succeeding these beds the clays gradually give way to shales, and the lower portion of the mountain was composed of bluish-gray shale interstratified with fine-grained yellowish-brown sandstone in layers three to six inches in thickness, while the shale beds are as much as a foot thick.

As previously mentioned, the section from Tutitlan to Orizatlan shows this position reversed. On the trail from Huejutla to Huautla along the Rio Capadero the shales are first encountered, and above these and forming a cliff is the sandstone. In the Chicontepec Mountains the town by the same name is located on the soft blue shales. To the immediate south and overlooking the town is a cliff that has an elevation of 2,650 feet (800 meters), or 575 feet (180 meters) higher than the town.

[1] *Ibid.*

The cliff proper is of the same sandstone which here is but little disturbed. In fact it is the hard sandstone capping of the shales that has prevented the forces of erosion from reducing the topography to the level of the plain to the east.

The sandstone member is at least 750 feet (230 meters) thick. Due to the close folding, faulting, overthrusting, and telescoping of the shale member, as well as the inability to distinguish its base, no estimate of its thickness will be made except to say that it is thicker than the sandstone member. J. J. Galloway, in a personal communication, gives 3,000 feet (925 meters) as a tentative estimate. Dumble states that it exceeds 2,000 feet.

The Chicontepec is of rather broad extent. It extends at least from Yahualica in eastern Hidalgo to the north-south line of production of the South Field, a distance of 72 kilometers (Fig. 1). Its north-south extent is not known.

Whether or not the Tanlaja series described by Jeffreys and mentioned by Dumble under his discussion of the Chicontepec[1] belongs to the Chicontepec is not at present known. Huntley[2] refers it to the upper Tertiary.

For the most part the Chicontepec series seems to rest conformably on the Papagallos. However, northwest of the town of Petlacatl, which is northwest of Tlanchinol, there appears what is evidently the flaggy Chicontepec sandstone member lying horizontally and unconformably on the Tamasopo at an elevation of 2,650 feet (800 meters).

Eocene—Alazan.—The name Alazan is applied to the thick series of shales, sandy shales, and soft sandstones that overlie the Chicontepec. It was named by Dumble from a small outcrop on Buena Vista River west of Alazan, Vera Cruz. His description is very meager, being confined to mere references such as "hard blue shales," "blue shales," "a bluish shale that weathers white," and "Alazan marl."[3] Only a very general description of the lithology and no quantitative description of the thickness of the formation is given. Dumble also states:[4] "It [the Papagallos shale] is succeeded by a shale so similar in color and general structure as to make a separation extremely difficult."[5]

[1] Dumble, "Geology of the Northern End of the Tampico Embayment Area," *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), p. 134.

[2] Huntley, *Trans. Amer. Inst. Mining Engineers*, Vol. 52 (1916), p. 303.

[3] Dumble, *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), pp. 141–43.

[4] Dumble, *Science*, Vol. 35 (1912), p. 907.

[5] It is to be noted that the Chicontepec is missing where this observation was made, i.e., on Conchos River.

The type locality gives a very poor exposure of this formation, though probably as good as can be found. The beds seem to have a flat attitude, though they are badly contorted by overthrusting, which will be discussed later (p. 1213). As described by Dumble there seem to be two horizons. The lower one is more or less uniform. There are depressions in the surface which are lined with what appear to be boulders. Above this there are a few remnants of a blue shale closely resembling the shale below. It is in this upper bed that the rather scanty fauna is found. The general structural relationship is suggestive that the boulder bed and the overlying shale were deposited by the present river. It seems entirely possible that the fossils were simply carried from another part of the underlying shale and deposited by river eddies. The fact that the upper shales are not contorted lends support to this view.

Dumble states[1] that Gester pronounces the fauna Tejon (upper Eocene of California) and Dickerson states[2] that it is a mixture of both Tejon and "the upper Eocene of the Gulf Coast." It is probable that the latter part only of Dickerson's determination will ultimately prove to be the correct one. As far as can be stated from personal observation of this fauna it is Atlantic in its affinities and not Pacific, and it resembles the Claiborne of Texas. This view is supported by a recent note by Dumble[3] in which he states: "In the Idolo Island well the samples from 1,268 to 1,800 feet showed the same assemblage of forms (foraminiferal) found in the surface material taken near the top of the Alazan (Jackson beds), while those from 1,800 to 2,500 feet correspond with the forms found in the Tantoyuca or Lower Alazan (Claiborne)."

This formation overlies the Chicontepec and is apparently conformable. East of the town of Chicontepec it is first seen at Francia, 24 kilometers from the coast. It conforms to the general low eastern dip toward the coast. The general trend of the contact is not known, but is probaby roughly northwest and southeast, in conformity with the main features.

At Francia the Alazan is represented by thinly bedded whitish shales with small lenses of sand and carbonaceous layers. The color is due to the effect of many small glassy basaltic dikes that locally alter the shales. These dikes do not affect the structure of the shales except very locally. Outside of the intruded area the shales very closely resemble the lower shale member of the Chicontepec and carry a few Foraminifera. Farther east, near Tepetzintla, where it is exposed in river cuts on the south side of

[1] Dumble, *Science*, Vol. 35 (1912), p. 907.

[2] Dickerson, *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1912), p. 142.

[3] Dumble, *Science*, Vol. 58 (1923), p. 31.

Sierra Otontepec, there are a few large soft brownish-gray sandstone beds. These beds have also been reported in wells.

The prevailing constituent of the Alazan seems to be a bluish sandy shale which on the whole is very uniform. This weathers to a rather light yellowish-gray clay that forms the floor of the flat area where this formation outcrops. The broad valley with only a few soft erosional remnants seems to be characteristic of the Alazan topography. This is in marked contrast to the hilly features of the sandy San Rafael to the east and the Chicontepec to the west.

Referring to the last quotation from Dumble, the evidence of the fossil Foraminifera indicates that the Tantoyuca beds are included in the lower part of the Alazan. However, from the lack of stratigraphic and of more complete paleontological data no definite statement of correlation can be made at this time.

The thickness of the Alazan is not known with any degree of accuracy. Five thousand feet is an estimate given in a personal communication by a geologist who had sectioned the formation south of Tuxpan River. Galloway gives as a tentative estimate 2,500 feet. The overlying San Rafael has a regional dip of 1° E. Based on the assumption that the underlying Alazan has the same attitude, calculations give it a thickness of 2,900 feet between Francia and Tepetzintla.

Oligocene—San Rafael (Fernando).—The Oligocene of the Mexican Gulf Coast was first described by Dumble,[1] who says: "We have called these the Fernando from the fine exposures of the beds in the vicinity of the town of that name on the Rio Conchos."

This name was found to be pre-empted and was later changed to San Rafael from another town situated on this formation. Professor Cummins had previously given it the name Fernando, but as far as is known had not published it.[2]

This formation differs considerably from the underlying Alazan in many respects. Dumble describes it[3] as "a series of yellowish sands, clays, and calcareous beds." In the vicinity of Tepetzintla, Zacamixtle, Tampico, and in the Topila Hills the San Rafael is made up very largely of a soft dull grayish sandstone with here and there a gravelly bed. Though very soft, it is much more resistant to erosion than the underlying Alazan, with the result that the dissected remnants form low isolated hills to the

[1] Dumble, *Proc. Cal. Acad. Science*, 4th series, Vol. 5 (1915), p. 189.

[2] Cummins, *Science*, n.s., Vol. 27 (1908), p. 273.

[3] Dumble, *Proc. Cal. Acad. Science*, 4th series, Vol. 5 (1915), p. 189.

west which overlook the broad uniformly flat or very low gently rolling "swells" that mark the east and west limits of the Alazan shales. Farther east, in the general vicinity of Zacamixtle, the San Rafael forms a more or less continuous range of hills trending generally northwest and southeast. These become lower and finally pass under the Pleistocene and Recent deposits near the coast.

The San Rafael contains a plentiful fauna. Two horizons are particularly persistent. One of these is an old coral reef. At Zacamixtle this coral bed is about 200 feet (60 meters) above the top of the Alazan. About 70 feet above this at Paso Real, east of Zacamixtle, is a bed of *Lepidocyclina* in which *Lepidocyclina gigas* var. *mexicana* Cushman occurs in large numbers. This fauna, which is low down in the San Rafael, has been correlated by Vaughan with the middle Oligocene of the West Indies. The San Rafael as a whole has been correlated by Vaughan[1] with the Antigua and Anguilla, the middle and upper Oligocene of the Antilles, and the Chattahoochee of the southeastern United States.

The San Rafael has been but little disturbed in the area under consideration except very locally in the vicinity of the volcanic plugs. It is essentially a shore and shallow-water deposit, as is evidenced by its lithology and fauna as well as the cross-bedding that is seen in places. At Zacamixtle it contains a few small well-rounded pebbles of the Tamasopo black chert. The presence of these pebbles will be commented upon under the head of "Historical Geology."

Erosion has reduced this formation to such an extent that between Zacamixtle and the coast there is not more than 350 feet of thickness remaining. In the Otontepec range, where it is covered by a thick mantle of basalt, there is about 400 feet more preserved, which makes a total thickness of 750 feet (225 meters). Farther north, in the vicinity of Cerro de las Rusas, this formation becomes much thicker and more extensive. Here it has a thickness of about 1,500 feet (475 meters).

Oligocene—Meson.—Dumble[2] makes the following comment on this formation:

> The type locality of the Meson beds is in the valleys lying between Moralillo and Meson on the trail leading from Tamiahua to Alazan. These beds consist for the most part of yellow sandy clays with some lime and sandstone. It is characterized by the large Foraminifera *Orbitoides papyraceae* Bou.

[1] Vaughan, *U. S. National Museum Bull. 103* (1919), p. 595.

[2] Dumble, *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), p. 147.

Cushman,[1] referring to *Lepidocyclina gigas* var. *mexicana* Cush. states:

> The type, from the Meson formation, Vera Cruz, Mexico, is referred to by Dumble under the name *Orbitoides papyraceae*. Large specimens that seem very similar occur in the material collected by Dumble from the San Rafael formation.

As previously stated, this foraminifer and its associated fauna occur *above* the coral bed that is middle Oligocene in age and well down in the San Rafael formation. It is therefore apparent that the term "Meson" can only be used in reference to the *Lepidocyclina* beds which are *within* the San Rafael, and not to a separate formation.

Miocene—Loup Fork.—Zacualtipan is situated on a remnant of the old highland at an elevation of about 7,000 feet (2,100 meters). Head erosion of the tributaries of the Panuco have cut deep *barrancas* on all sides. These have exposed the underlying formations which are seen to consist of a series of interbedded tuff beds, basalt flows, and beds laid down under lacustrine or terrestrial conditions. Among the latter are sandy beds carrying fresh-water gastropods and thin deposits of lignite. In these sedimentary deposits Cope found horse teeth which enabled him to correlate these beds with the Loup Fork, middle Miocene, of the western United States.[2] As the sediments and the basalts are interbedded it is evident that they both belong to the same period. The sedimentary beds lie horizontally and are not disturbed, though they have been roasted and melted by the basalt that flowed over them. These beds represent intermittent volcanic activity and periods of quiescence, as will be discussed under "Historical Geology." A discussion of the basalts will be taken up under the head "Plug Basalt" (p. 1202).

Near Metzquititlan, on the divide between Los Venados and Milpillas, are thick white tuff deposits which also carry lacustrine or terrestrial gastropods and many well preserved leaf impressions of netted-veined, broad-leaved trees. This lies just above a bed of basalt and is probably contemporaneous with the Zacualtipan deposits. It is of passing interest to note that the basaltic series in the former locality rests on the Necoxtla, while at Zacualtipan it rests on badly contorted and intruded sediments whose identity is wholly unknown. In the latter locality the total interbedded Miocene series has a thickness of 750 feet (230 meters).

Miocene—Tuxpan.—The Tuxpan formation was named by Dumble[3]

[1] Cushman, *U. S. Geol. Survey, Prof. Paper 125* (1920), p. 63.

[2] Cope, *Proc. Amer. Phil. Soc.*, Vol. 23 (1886), p. 146.

[3] Dumble, *Science*, n. s., Vol. 27 (1908), p. 273.

in his description of the sandy beds which make up the low hills at Tuxpan, Vera Cruz. These beds are composed of soft yellowish, loosely consolidated sandstones that lie practically horizontal and have been but little disturbed except for elevation. About 65 feet (20 meters) are exposed at Tuxpan. Their areal extent is not known.

Regarding their relations to the San Rafael, Dumble[1] states:

> While the contact between the Tuxpan and San Rafael beds has not been positively observed, we may conclude that a decided unconformity exists because there are numerous small anticlines to be seen in the San Rafael, while the Tuxpan beds seem to show little or no disturbance of this character. A further study will probably demonstrate that south of the Otontepec divide the Tuxpan beds overlap the San Rafael in many places, as they certainly do in the region of Tordo Bay.

QUATERNARY

Pleistocene: Reynosa and marine deposits.—The Reynosa consists of river gravels and loosely consolidated conglomerate that form the capping of many of the small erosional hills along the western front of the San Rafael outcrops, and more or less continuous beds farther east where the elevation is less and the work of erosion less extensive.

It is also found high up on the slopes of the approaches to the volcanic plugs. It occurs on the slope of Cerro Tepenahuac at an elevation of 1,600 feet (500 meters) above sea-level, and 1,300 feet (400 meters) above the floor of the valley. It is found on the sides of Cerro Texixco near Tepetzintla at the same elevation.

The Reynosa has the same lithologic features as in northern Tamaulipas, except for the presence of a large basaltic boulder content from late basaltic intrusions. The milling action of the water is well shown wherever the Reynosa appears. The relatively softer limestone with black chert bands is seen very commonly among the boulders to the west. Farther east this feature alters and the harder black chert with here and there a fragment of the former limestone matrix clinging, together with basaltic boulders from the plugs, make up the boulder content.

This formation post-dates the San Rafael by a considerable period, as is shown by the eroded surface and the unconformable contact between them.

The marine Pleistocene has been but little studied. Personal information of a private nature is to the effect that it is found in the banks of Panuco River a few feet above sea-level.

[1] Dumble, *Proc. Cal. Acad. Science*, 4th series, Vol. 8 (1918), p. 149.

IGNEOUS ROCKS

OLDER INTRUSIONS AND FLOWS

The igneous activity of eastern Hidalgo and the area of Vera Cruz that is under consideration is for the most part Tertiary in age, and the intruded and extruded material basaltic. To this there are a few exceptions. The presence of diorite boulders in the bed of Chiflon River evidences the existence of diorite intrusions in the drainage of this system. However, no published nor further private data are at hand on this point. In the bed of the Rio Mesquite at Huayacocotla may be seen a badly altered andesite intruding the Lias. The age of this is not known. Above the Necoxtla where it appears in a canyon north of Zucualpam is an exposure of altered andesite. The presence of andesite flows *within* the Cretaceous has been noted by different observers since Von Humboldt's time. Wittich has given a clear statement of this feature.[1]

South of Zacualtipan beds of basalt are seen to lie apparently conformably between beds of Tamasopo limestone. This basalt has weathered in marked contrast to the later Tertiary basalt. It evidently represents Turonian volcanic activity.

RHYOLITES: TERTIARY

There is a local petrographic province that seems to be the most extensively developed in an area that begins a few kilometers north of Zacualtipan. Here for several square kilometers the entire country is made up of rhyolite. Ordonez[2] mentions the rhyolite of this province. Here the rhyolite is faulted, tilted, and overthrust to a noticeable extent. In level places where it is protected from erosion it weathers to a residual pure white kaolin which is 2 or 3 meters thick. Below it grades down into the unaltered rhyolite. The unaltered rock contains many lithophysae.

This province thins out to the south and only remnants are seen near Carpenteros and near Huayacocotla.

To the north it is seen rather extensively developed in the vicinity of Molango. Just south of this town there is an eroded remnant of a large plug, the peaks of which are known as San Roa and Cerro Timimilco. The presence of many fragments of basalt, shale, and limestone on the summits of these peaks indicates that the intruding material did not reach the surface at the time of the intrusion but has later been exposed by erosion.

[1] Wittich, *Mem. Soc. Cien. Antonio Alzate*, Vol. 38 (1920), p. 415.

[2] *Instituto Geologico, Bol. 14*, pp. 9, 19, 38, 61, 67.

Several large dikes radiate from this intrusion. One of these forms a high precipitous peak, Cerro de la Campana, which is 750 feet (225 meters) high. In passing it is worthy of note that the north-south dikes lie in the divide between two large branches of Panuco River.

West of Molango in the twin peaks of Cerro Pelon (8,750 feet or 2,660 meters) and Cerro de Agua Frio (9,050 feet or 2,750 meters) a large intrusion may be seen in a fault plane which will be mentioned later.

North of Molango, at Quetzaltzongo, extensive faulting has exposed a line of peaks composed of rhyolite and rhyolitic tuff (see p. 1205). This fault has a bearing of N. 45° W., roughly paralleling the main structural features. It is probable that field investigation to the north would show further remnants of this rhyolitic province.

BASALTS

OLDER TERTIARY

In the canyon east of San Bernardo, south of Zacualtipan, is a decomposed basaltic dike intruding the Tamasopo limestone. This has locally marmorized the limestone and also furnished the conduit for the solutions from which the iron was precipitated in the limonite mine of that locality.

Traces of an old basaltic flow are seen around Molango. These are intruded by the Cerro de la Campana rhyolitic dike. On the southern edge of Quetzalzongo (between Molango and Tlanchinol) is an old badly decomposed basaltic dike.

The meager presence of this old basalt indicates a relatively old period of limited volcanic activity.

Huautla basalt.—In the region around Huautla and extending west into the eastern part of Hidalgo there is a conspicuous broad, extensive basaltic plain. This has an elevation of 2,000 feet (600 meters) at Huautla and 2,500 feet (800 meters) at Yahaulica, and continues to rise westward at about the same rate. This is the old surface described under the head of "Topography." The term basalt is extended to include the agglomerates and tuffs which make up a considerable part of this series.

For the most part the basaltic members are much decomposed and soft. Where the tuff is exposed at the surface it has decomposed to a red mud or clay. In the fractured areas concentric weathering has reduced the basaltic fragments to rounded boulder-like forms with a shelly surface. Practically all the minerals of the whole series show decomposition in various stages, depending upon whether they are in the more massive basalt or the finely divided tuffs. The one unaltered mineral is magnetite, which abounds where it has been milled out in the small washes.

The thickness of the series ranges from 250 feet (80 meters) to 450 feet (135 meters) in the general vicinity of Huautla.

This Huautla basalt rests upon the Chicontepec beds. At Huautla it rests on the upper sandstone member, and farther west, on the lower shales. It is very probable that still farther west it would be found lying on the Cretaceous. Between the Huautla basalt and the Chicontepec there is a clear unconformity, as this observation indicates. The deep canyon of the Rio Yahualica exposes basins of 200 feet (60 meters) in the surface of the Chicontepec.

The age of the Huautla basalt is not known. From its stratigraphic position it is younger by at least one erosional interval than the Chicontepec, as shown by its position on the folded Chicontepec shales west of Huautla. At Francia and Tepetzintla the Alazan is intruded by decomposed basaltic dikes. In the latter locality boulders of a similar basalt are found above the Alazan–San Rafael contact. If the suggestion is of any merit that these latter intrusives were a part of the same activity that produced the Huautla flow, then it could be stated definitely that the Huautla basalt is at least post-Alazan and pre–San Rafael in age.

The name Huautla basalt was taken from the town of that name which is located on this formation.

This formation was involved very little or not at all in the folding of the Hidalgo anticline, which will be described later (p. 1203).

Plug basalt.—This term is applied to the basalt that makes up the plugs that are such a conspicuous feature of this part of the coastal plain and also the very extensive flows that formerly covered the western part of Vera Cruz and eastern Hidalgo. These flows still persist as the more or less continuous effusive mass that forms the surface rock of this part of Hidalgo. In the former area the Otontepec Mountains represent the sole remnant of the surface flows that has survived the action of erosion.

This formation is made up of a series of basalts, agglomerates, and tuffs, together with a few beds of pumice. In the vicinity of Zacualtipan the formation contains a few terrestrial beds (p. 1198). South of Zacualtipan a few kilometers is a small local capping of obsidian. Approach to this area from any quarter is marked by an increase in the number of arrowheads, spearpoints and other implements that are widely distributed, indicating that this obsidian formerly furnished the raw material for an extensive stone artifact industry. This material was poured out by the several volcanoes whose sites are now marked by the volcanic plugs of the lowland and by the few small hills on the edge of the highland.

The thickness of the large effusive mass is variable, due to surface

erosion and also to the fact that it was laid down upon an uneven surface. The thickness at Tlanchinol is 1,300 feet (400 meters); at Huayacocotla, 1,400 feet (425 meters); at Durazno 1,750 feet (530 meters); and between Huayacocotla and Zucualpam it is 2,250 feet (880 meters).

Wherever this formation is seen the basalt member has always a fresh appearance. Detailed examination of the mineral components shows little or no decomposition. The agglomerates likewise show but incipient stages of disintegration. The pumice and tuff also are but little altered beyond the slight oxidation of the femic minerals. The pumice is still hard and resistant and is used for road material.

This basalt post-dates the leading structural events of the entire region. It is found lying unconformably on the Tamasopo, San Felipe, and the Papagallos shales north of Tlanchinol and the Huautla basalt west of Huautla. Field observation thus far furnishes no evidence that it took any part in any of the folding in the entire area.

Age.—The age of the Plug basalt is not definitely known, though it is probably middle Miocene, being contemporaneous with the Loup Fork beds; at least it can be definitely stated that a part of the series belongs to this horizon from the following evidence: This basalt forms the surface rocks and the high clifflike rim that is seen in the deep canyons from Zacualtipan east to the edge of the highland where it has not been removed by erosion. It has already been stated that this basalt is interbedded with lacustrine beds that carry Loup Fork Miocene horse teeth. As these sedimentary beds are in the lower part of the series, it is possible that the upper part of the Plug basalt is upper Miocene or in part even younger.

STRUCTURE

MAIN STRUCTURE

The main structural features of the area under consideration are relatively simple. They consist of a very large anticline on the west, the eastern limb of which flattens out and the formations composing it continue eastward to the Gulf (Fig. 8). For convenience the anticline will hereinafter be termed the Hidalgo anticline. The axis of this anticline has a bearing of N. 25° W. and lies in a line connecting Zucualpan in western Vera Cruz and Tlanchinol in northeastern Hidalgo. These are not the limits of its north-south extension, but merely serve to locate it geographically. The flat extension of the eastern limb toward the Gulf is somewhat complicated along its eastern border by the presence of a rather large faulted anticline with a small incipient overthrust which is the line of production

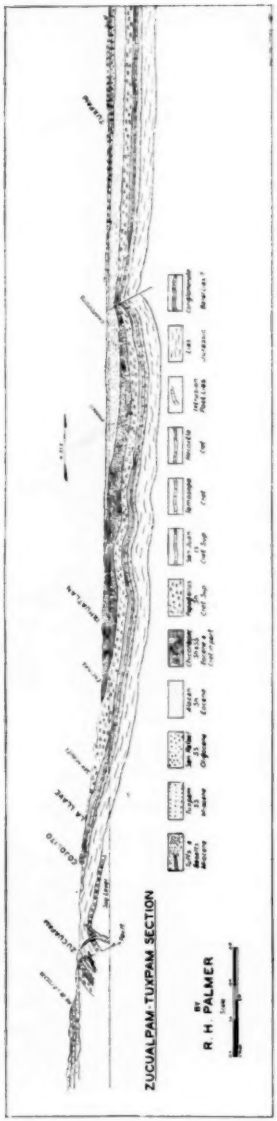


FIG. 8.—Geologic section from Hidalgo to the coast

of the South Field. It is very probable that between this and the Hidalgo anticline there are many other minor folds and undulations.

In the eastern limb proper there are several minor structures, some of which are in the form of close folds, overthrusts, and telescoping of strata due to the relative incompetency of contiguous beds, and others are due to the intrusions.

MINOR STRUCTURES ON THE HIGHLAND

On the highland in the anticline proper there are many complications in the form of faulting, block-faulting, horizontal faulting, overthrusts, and intrusions that deserve special mention.

At Molango horizontal faulting has produced some modifications in the main structure. This faulting and resulting overthrust can best be explained by a horizontal plan and a vertical section (Figs. 9 and 10).

It is evident that the lateral pressure that resulted in the large anticline was from the east. Apparently this compression was not everywhere equal or the westward moving mass met with varying resistance along its front. Where a portion of the mass met with sufficient resistance it was held back and adjacent parts moved on. The complicated movements are somewhat analogous to those of contiguous segments when a broad ice floe meets with obstructions in the form of islands or shore irregularities. These movements were accompanied by long horizontal faulting

which divided the main mass into long east-west segments and by minor folding east of the resisting mass and finally by extensive off-sets in the axis of the Hidalgo anticline. A case in point in Cerro Pelon and Agua Fria (Fig. 9). These two peaks were thrust westward 7 kilometers from their former position in line with San Roa and Cerro Timimilco.

A short distance west of Quetzalzongo is a system of faults trending northwest and southeast. The lateral pressure here was relieved by three parallel faults which form three lines of peaks. The throw of the main fault is at least 1,100 feet (340 meters). (See p. 1201.)

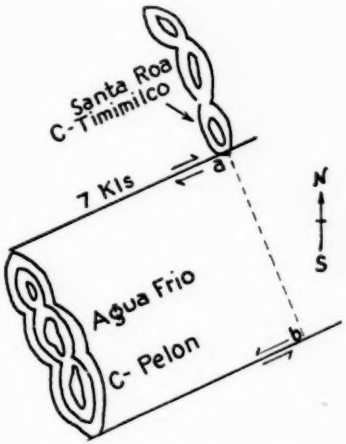


FIG. 9.—Plan of ridges near Molango, Hidalgo, showing segments and accompanying horizontal faults due to unequal resistance to pressure from the east. The Agua Frio–Cerro Pelon segment was thrust westward 7 kilometers from its former position, *a–b*.

The adjustments to the lateral forces, together with erosion at times, have resulted in other minor topographic features that are more or less conspicuous, such as fault blocks and sunken and elevated blocks. Some fault blocks are caused by erosion in a deep canyon cutting away the lateral support, which allows a slumping. The town of Molango is located on a block that settled between high walls of resistant masses. The presence of two small lakes and the hummocky topography seen a few kilometers west of the town bear evidence of the compression suffered by this wedge as it settled between the resistant converging walls.

Cerro Tlanchinol is a block or wedge that represents a locality where the adjustments took the form of an elevation. These blocks or wedges are all on a scale very small compared with the similar forms in the Great Basin of the western United States, which is the type locality of this structure. They are measured in kilometers of extent, while the latter are measured in hundreds of kilometers. Their size permits them, or several of them, to be seen at one glance. They have the general appearance in the distance of small inclined flat areas that are in marked contrast to the surrounding country.

The eastern limb of the Hidalgo anticline presents but minor features of note. The thrust segments that have been mentioned have given it a more or less zigzag outline. There are a few intrusions that are apparently very local. The different rock combinations of relatively massive limestone, thick and thinly bedded limestone, sandstone, and shales have resulted in the well-known reciprocal structures incident to contiguous competent and incompetent formations.

There is one detail of the latter that deserves special mention in connection with the Chicontepec series because of its marked effect on the topography of the area where the Chicontepec forms the areal geology.

FIG. 10.—NE.-SW. section through Agua Frio, showing overthrust. The Cenomanian shale is capped by Turonian limestone. The basal (?) conglomerate probably rests on the Lias. *a*, Turonian, *b-b'*, Cenomanian (Necoxtla).

Lateral thrusting in the vicinity of the Chicontepec only gently folded the hard sandstone and left it in a series of low plunging anticlines and synclines with a rolling topography. In other places where erosion has not removed the sandstones and they are sharply folded and overthrust there results a series of topographic features and structures that are of one type, namely, a ridge of sandstone formed by close folds or overthrusts, resting on the shales below. Between Orizatlan and Huitzitzilingo to the west is a hill of Chicontepec sandstone whose structure is typical. Evidently in the area east and west of this hill the hard sandstone was folded and fractured to greater extent than in the hill itself. This allowed erosion to operate more energetically and reduce these fractured areas to the general level of the low plain, while the area where the fracturing was less remained as a hill. The elevation of this hill is 1,400 feet (425 meters) or 500 feet (150 meters) above the surrounding country.

From a high vantage-point long ridges of this kind are seen to form the most conspicuous features of the Chicontepec landscape.

MINOR STRUCTURES ON THE COASTAL PLAIN

Intrusions.—The long monoclinal fold from the eastern limb of the Hidalgo anticline to the coast has been modified both by the extensive

intrusions and by the lateral pressure that formed the major structures. Little information from field observations is available, as the terrain for the most part is relatively flat. The published data are largely theoretical. All that can be stated from personal observation is that the effect of the intrusions on the Alazan shale was very local and did not in any way affect the general structure.

The effect on the more brittle and hard Tamasopo and San Felipe was probably largely one of fracturing.

Structure of the plugs.—The plugs for the most part are steep-sided and circular above the surface, and the well records indicate that this condition continues below the surface. Dikes radiate from the plugs in different directions without recognizable system. However, north of this area L. G. Huntley finds that there is a "general agreement between the strike of the sedimentary formations and the main dykes of the coastal portions of the fields."[1] Some of the dikes appear at the surface and others are encountered only by the drill at depths.

Some of the hills that are in the plug area have every appearance of plugs but, strictly speaking, are not. Zaragosa Hill at Amatlan is composed of baked San Rafael sandstone. In the periphery the beds are seen to dip toward the hill, indicating that the intruding basalt did not reach the surface and later withdrew, allowing the settling of the intruded sedimentary beds. The presence of the plug below the surface is shown by the basalt dikes that were found in near by wells. Huntley[2] mentions similar observations made here and at Aguada.

Lateral pressure.—The lateral pressure that caused the major structures caused also minor structures that were of much more importance than those caused by the intrusions. These are small folds on the long monoclinal extension of the eastern limb of the Hidalgo anticline. The east-to-west pressure was apparently transferred to the west as far as the Hidalgo anticline, and this was elevated until sufficient resistance accumulated to prevent further release of pressure along this line. Thereafter the accumulating lateral pressure formed minor folds along the monocline. One of these, which has already been mentioned (p. 1204), is the fold and incipient overthrust accompanied by faulting that runs from San Geronimo to Chapopote Nuñez. It is along this that the production of the South Field occurs and will be hereinafter referred to as the South Field anticline. In the specific area under consideration there are no other

[1] Huntley, *Trans. Amer. Inst. Mining Engineers*, Vol. 52 (1916), p. 306.

[2] *Ibid.*, p. 312.

proved folds. However, both to the north and south minor folds have been reported and future drilling will very probably show their existence.

South Field anticline.—The great economic value of the South Field anticline warrants a description of this structure. The geographical locality has already been given. Reference to the plan given on the map (Fig. 1) shows this to be a broad arc with the convex side to the west. The interpretation of this seems to be that it is a segment being thrust westward similarly to the Agua Frio–Cerro Pelon segment (see p. 1204). It appears that Tuxpam River may occupy the horizontal fault between two such segments, as the line of production of the South Field does not continue on the south side of the river, that is, either the anticline does not cross the river or is offset on the south side and its location to the east or west not yet determined.

The anticlinal structure is but scantily reflected at the surface but is shown by drilling records. East of the axis the several formations, except the Chicontepec, are encountered at gradually increasing depth.[1] However, on the west side of the fold the formations drop off sharply. Wells but a short distance west of the line of production have been sunk 4,000 feet and, it is said, have not reached the base of the Alazan. This would indicate that the west limb was faulted downward or that there is an overthrust from the east. That there has been considerable fracturing along this line is shown by the brecciated Tamasopo that is in places blown from the wells. Many of these pieces also show crustifications of calcite on angular surfaces.

Fracturing and faulting are also indicated by anomalies encountered in wells close to each other. Dry wells or salt water or gas are encountered in many wells at depths greater than production in others but a few hundred meters distant. Also in many contiguous wells a great difference in the pressure is encountered. This is particularly the case in the Panuco area.

A contour of the axis of the South Field anticline from Amatlan to Almo made by an engineer of one of the companies from the best information available shows that the top of the Tamasopo is a series of high places and saddles ranging from 1,300 to 2,100 feet subsea-level, with a gradual lowering to the south, that is, the anticline is gently plunging to the south. The producing wells on the whole are located on these convexities. The

[1] Dumble (*Science*, n. s., Vol. 58, p. 31) states that drilling records from wells on Idolo Island between the bottom of the Tantoyuca Lower Alazan at 2,500 feet and the top of the Papagallos at 4,200 feet show a horizon that "was probably the coastal representative of some part of the Chicontepec of the interior region."

general conclusion seems to be that the oil in the South Field anticline is located in a series of pools quite independent of each other.

Along this anticline is arranged the second line of plugs mentioned on page 1178.

There is evidence to the effect that the South Field anticline dates from approximately the same period as the Hidalgo anticline. Along the crest of the former the Alazan rests in places on the Papagallos, in others on the San Felipe, and in still others, for example, near Zacamixtle, it is reported to rest directly on the Tamasopo. Nowhere, as far as personal knowledge goes, does the Chicontepec appear along the crest of the South Field anticline, though it has been found to the west a short distance and Dumble reports on Idolo Island what appears to be Chicontepec. These facts lead to the conclusion that the South Field anticline was folded after the deposition of the Chicontepec. It was noted (p. 1191) that the Chicontepec is the youngest formation that participated in the folding of the Hidalgo anticline, and it is shown (p. 1212) later that the Huautla basalt which lies in a nearly horizontal attitude above the folded Chicontepec in this locality is probably late Alazan or pre–San Rafael in age. Furthermore, the similarity of the attitude of the Alazan where it appears nearest the Hidalgo anticline and near the South Field anticline indicates that the folding for the most part occurred prior to the late Alazan.

The varying beds subjacent to the Alazan are explained by the elevations and saddles along the axis where the effect of erosion was proportional to the elevation. The erosion of the high points of the anticline prior to the Alazan deposition indicates subaerial conditions.

HISTORICAL GEOLOGY

JURASSIC

The earliest recorded history in this section commences with the Liassic or lower Jurassic. If the conglomerate bed at the base is the basal conglomerate of the Lias this period was initiated by a sinking shore line and the consequent encroaching of the sea. The direction of the land mass from which the conglomerate and later shales were derived is not known, though it very probably was to the north. The Lias deposits indicate quiet waters and abundance of life, conditions not unlike those found in large estuaries on the continental shelf today. These conditions continued throughout a long period of time. In the Oaxaca Lias and in the upper parts of the beds at Huayacocotla the presence of plentiful plant remains is indicative of swamp conditions.

From the Lias to the Cenomanian there is no geological record in this

locality. Burkhardt reports the Oxfordian, Kimmeridgian, and Portlandian in Durango[1] and the Kimmeridgian and Portlandian in Zacatecas.[2] Böse procured fossils in Guererro which Burkhardt pronounces Upper Dogger.[3] Böse and Burkhardt, in their extensive work in Mexico, report the Neocomian, Aptian, and Albian. It is probable that sediments of these ages were also laid down in Hidalgo and Vera Cruz but were eroded prior to the deposition of the Cenomanian, though it is possible that this area was a land mass during the greater part of this time. The presence of the conglomerate at the base of the Cenomanian in Jalisco and the shallow-water deposits and fauna of Hidalgo, however, seem to indicate that the first interpretation is the more probable.

CENOMANIAN

On the west coast in Jalisco the Cenomanian, to which probably belongs the Necoxtla, was initiated by an oscillating floor on which the interbedded conglomerates, shales, and limestones were laid down. This was shortly followed by a general rising and the deposition of a thick series of sandstones that are in part terrestrial, and these in turn were followed by deposits of gypsum and anhydrite, products not only of terrestrial, but also of desert, conditions. In Hidalgo and Vera Cruz the history is parallel. The lower beds are distinctly marine, but near the top the beds of wad bear witness to marshy areas. The specific differences found in these different localities are explained by the proximity of the former to the land mass from which its sediments were derived and the greater distance of the latter.

The Cenomanian period was brought to a close and the Turonian initiated by a rapid sinking of all of Mexico, at least as far north as San Luis Potosi and south to the Isthmus of Tehuantepec, and the advance of the sea from the Atlantic side. The Tamasopo limestone was laid down on the floor of this mediterranean sea.

During both the Cenomanian and Turonian times there was an intimate connection with this continent and Europe and Africa. The faunas of these formations belong to genera that are entirely Atlantic and totally unlike the fauna of the Cretaceous of western North America. The same observation has been made by Douvillé,[4] who termed the expanse of water

[1] Burkhardt, *Inst. Geol. de Mexico, Bol. 29* (1912), pp. 209–22.

[2] Burkhardt, *ibid., Bol. 23* (1906), pp. 142, 147; *Bol. 33* (1919), pp. 1, 15.

[3] Böse and Burkhardt, *Inst. Geol. de Mexico, Paregones*, Tom. 3, No. 5 (1911), p. 283.

[4] Douvillé, *Bull. Geol. Soc. France*, Vol. 28 (1900), p. 222.

with a common fauna "Mesogee." This is the Cretaceous extension of the "Tethys" sea described by Suess.

TURONIAN—CHICONTEPEC

The Tamasopo limestone indicates an encroachment of the sea with either comparatively deeper water or very low adjacent land masses, as is shown by the paucity of shale beds within this formation. This incursion of the sea extended at least to Jalisco, Colima, and Oaxaca, and probably farther. There was no mingling of Pacific and Atlantic faunas, evidencing a land mass to the west—probably an extension of Lower California. The presence of more shale beds to the north indicates that the land mass was to the northwest.

From the Tamasopo to the top of the shale member of the Chicontepec there seems to be a general conformity. A few unconformities appear in local thickening and thinning of beds, but these may be due to local disturbances and do not affect the general stratigraphic conditions. The transitional nature of the San Felipe has been mentioned by Huntley (see p. 1187) and others. The more or less massive Tamasopo, the bedded limestone of the San Felipe with thin beds of shale grading upward into predominating shaly members and thence into shale, followed by the Papagallos shales and marls, and these in turn by the Chicontepec shales, all bear evidence of a general uplift of the country and the recession of the sea.

It seems probable that the sandstone and the subjacent shale members of the Chicontepec series represent continuous deposition, as the lower part is interbedded with the shale. The sandstone, however, denotes the presence of shallow-water and shore deposits. In the general area around Chicontepec the presence of *Lycopodium*, reeds, and *Equisetum* casts is indicative of swampy areas adjoining the shore, not unlike what appear today in parts of the coastal plain. At Ixhuatlan, however, these sediments carry marine *Bryozoa*. The upper part of the sandstone member as seen west of Chicontepec has worn fragments of a pearly shell that resembles fresh-water *Unios*. If these are true *unios* this stage represents the farthest withdrawal of the sea of this period.

HIDALGO ANTICLINE—ALAZAN SHALE—HUAUTLA BASALT STAGES

The intimate interrelations of these three periods warrant their discussion together. The immediate events following the sandstone stage of the Chicontepec are not clear. It is known, however, that the lateral forces that resulted in the folding of the Hidalgo anticline were initiated

at the close of the Chicontepec. The extent of this was, however, great enough to elevate the Chicontepec sufficiently to allow erosion to remove the sandstone member and a part of the shales on the eastern limb of the anticline, as is shown by the position of the Huautla basalt upon these shales. It is very probable that more extensive field examination would show that in places all the Chicontepec and a part of the Cretaceous was removed over the axis of the Hidalgo anticline before the Huaulta basalt was extruded. It is even probable that the anticline nearly reached its present attitude before the advent of this basalt, that is, the Hidalgo anticline is for the most part Alazan in age.

This condition is indicated by the presence of the very flat Huautla basalt with only a 1° dip on the steep eastern limb of the anticline. This low slope may be interpreted either as a slight participation in the folding or the slope of the surface on which it was laid down. The former is probably nearer correct, as it is known that there have been movements in this general area since Pleistocene times.

There is another line of evidence that indicates that the Hidalgo anticline reached practically its present attitude between the end of the Chicontepec and the close of the Alazan stage. The presence of the only slightly monoclinal fold in the Alazan shales alongside of the folded Chicontepec (Fig. 7) indicates that some time after the sandstone stage of the Chicontepec the folding was initiated and the Hidalgo anticline took form accompanied by a submersion of the area to the east together with the appearance of a low syncline along the eastern front which admitted the waters of the Gulf in which the but little disturbed Alazan shales were deposited.

It is probable that the Alazan sea extended as far west as the present town of Chicontepec, but erosion has removed its deposits until their farthest western extent now is at Francia, where marine Foraminifera evidence their marine origin.

It has been previously suggested (p. 1202) that the dikes of decayed basalt found in the Alazan represent a period of activity contemporaneous with the extrusion of the Huautla basalt. This would place the first period of volcanic activity as post-Alazan and following practically the completion of the Hidalgo anticline. This explanation seems probable in view of the fact that the folding would result in the fracturing and weakening of the strata, which in turn would facilitate the intrusion of molten material. On general principles it is well understood that periods of folding are usually followed by volcanic activity.

The crustal movements incident to the South Field anticline con-

tinued at least through the Alazan stage. This is well shown in Dumble's type locality. It happens that this is located over the axis of this structure. Mention was made before (p. 1195) of the contorted aspect of the beds. This is due to their presence over this area of structural activity and is evidence that the activity continued at least through Alazan time.

The muddy shale and the few soft sandstone members of the Alazan indicate that during this time the sea was shallow or only moderately deep.

OLIGOCENE—SAN RAFAEL

Sufficient study has not been made of the Alazan–San Rafael contact to warrant a discussion of the relationship between these two formations. An unconformity has been reported to divide them and this seems probable, judging from the rather distinct lithological differences that mark the two. The San Rafael is distinctly a soft sandstone formation with a few beds of coarse gravel. It is a near-shore deposit with a tropical fauna that is West Indian in type and indicates some sort of a land or shallow-water connection between the two areas.

The existence of the Hidalgo anticline and the removal of a portion of its overlying sediments at the time of the deposition of the San Rafael Oligocene is shown by the presence of the Tamasopo black chert pebbles in this formation.

That the South Field anticline was complete or nearly so before the deposition of the San Rafael is indicated by the low and apparently uniform dip of this formation from Tepetzintla, which is west of this structure, eastward to the coast. It is possible that some disturbances occur in the San Rafael over this anticline, but no data on the point are at hand.

MIOCENE: TUXPAN–LOUP FORK

As far as published data are available the status of knowledge of the San Rafael–Tuxpan contact is the same as in 1918, when Dumble recorded the statement quoted on page 1199. The fact that the two carry a few fossil forms in common indicates that there was practically a continuity of deposition from middle Oligocene through the lower Miocene, together with similar conditions of sedimentation.

The presence of the Miocene at Tuxpan and its absence, so far as known, to the north indicate that the general uplift that finally left the Tertiary beds at their present attitude was differential, and the withdrawal of the waters of the Gulf was delayed in the later rising area around Tuxpan and the south. This is further evidenced by the upper Miocene

and lower Pliocene faunas, described by Böse,[1] from areas farther south in Vera Cruz and Oaxaca.

PLEISTOCENE

The events of this period have left but little evidence. The wide extent of the remnants of the Reynosa that are now incised by the present drainage indicates that the general area was reduced nearly to base level when it received the Reynosa mantle. This mantle has the appearance of being the deposit of rather rapidly flowing streams that came from a steep topography out over a low flat area where the lessened gradient resulted in the deposition of the load and the rapid damming up in places, followed by frequent changing of courses, the final result being the patchy though widespread boulder beds that are seen so generally in this area.

The slight elevation of the marine Pleistocene has already been mentioned (p. 1199).

EROSION

The forces of erosion have operated on such a large scale in the area under consideration that they warrant a separate discussion. The most spectacular erosional features are seen along the eastern edge of the Anahuac Desert Plateau where the water courses have only deeply incised the old surface, making deep canyons with the intervening old level still intact. These features have been described under "Topography."

However, it is on the Gulf Coastal Plain that the effects of erosion reach their greatest proportion. It is probable that formerly there was a general slope from the Anahuac Desert Plateau with an elevation of about 7,000 feet (2,200 meters) to the general level of the summit of the Otontepec Mountains (3,200 feet or 1,000 meters). Erosion working backward to the west has removed the block of Tertiary that is bounded on the west by the harder Chicontepec and the Cretaceous limestones that flank the plateau. This block was at least 6,500 feet (2,000 meters) thick on the west, and 3,200 feet (1,000 meters) on the east, and 40 miles (50 kilometers) wide. In a strip 25 kilometers wide from the plateau to the coast, calculation shows that 1,875 cubic kilometers have been removed. If this is added to the amount of material whose volume is represented by the deep canyons of the adjacent parts of the highland, it is seen that 2,000 cubic kilometers is a conservative estimate of what erosion has accomplished in but a small fraction of this topographic unit of Mexico.

A question might arise, without going too far afield, as to the deposition of all this material. A glance at a relief map of the adjacent parts of

[1] Böse, *Inst. Geol. de Mexico, Bol. 22.*

the Gulf of Mexico shows an extensive deep which under static conditions would scarcely seem possible with the reception of several thousand cubic kilometers of sediment. As there is no other outlet or location where dispersal was possible, it is suggestive that this part of the Gulf sank roughly as the weight of the sediments accumulated.

ECONOMIC GEOLOGY

WATER POWER

As previously stated many streams flow through the deep canyons of eastern Hidalgo. Practically throughout their courses in this area these streams are a series of cascades. Along these steep gorges which in places are 3,300 feet deep there are admirable dam sites in which could be developed several hundred thousand horsepower. It is a conservative estimate that there is potential power in eastern Hidalgo to supply electricity for the principal industries in Mexico.

AGRICULTURE

Owing to the relatively low rainfall on the plateau the agricultural possibilities of western Hidalgo are rather limited. The presence of the deep canyons along the eastern edge and almost total lack of level land likewise preclude this section from being agriculturally important. However, the broad strip of low flat country underlain by the Alazan shales (see p. 1196) is exceedingly fertile. Weathering has altered the shaly material to a sandy clay, and vegetation has added its decayed débris until stream cuts show from 2 to 10 feet of humus. The rainfall here is somewhat heavier than to the west, with the result that the vegetation forms either a jungle or low dense underbrush, and in places grassy prairies. Many of the latter are several miles wide and the grass is so high that it obscures the view of a man on horseback.

Prior to the Madero revolution several large banana plantations bore evidence of the fitness of this country to produce tropical fruits.

There are several hundred thousand acres of this soil, the agricultural possibilities of which rival those of any other part of Mexico. The extensive grass-covered sections with many water courses are well adapted to stock-raising on an extensive scale.

PETROLEUM

Mexico has produced more than 1,250,000,000 barrels of petroleum and occupies second place in the world-production. Practically all of this

production comes from two relatively close areas: the Panuco and the South Field. The latter field is in the region under discussion.

The main structural features of the whole area have already been discussed. A few minor theoretical considerations may be of economic interest. It was suggested (p. 1207) that there were probably minor folds on the broad area that extends from Hidalgo east to the coast, and that the South Field anticline was one of these. The presence of the series of mountain ranges, collectively referred to as the Tamaulipas Mountains for convenience, on the north, and their disappearance at the north edge of the so-called "Tampico Embayment," suggest that their structures may continue to the south through this part of Vera Cruz, but are masked at the surface by the later sediments and by erosion that has left the surface very low and level.

Personal communications from geologists who have worked in the north end of the embayment and from others who have worked in the general vicinity of Papantla in the south report that minor structures are in evidence, paralleling the general structure. This would indicate that these structures in the north and south were possibly continuous under the broad area between the Hidalgo and the South Field anticlines (see p. 1204). From strictly theoretical considerations it would be very unlikely that the lateral pressure from the Gulf (p. 1207) would result simply in one major and one minor anticline separated by 25 miles of horizontally lying beds.

If these structures in fact exist it seems probable that production will be encountered west of the South Field. At any rate it would seem that there are sufficient considerations to warrant an extensive study of the whole Tampico Embayment and its borders, particularly to the north and south, with the view of determining the petroleum possibilities of the broad area between the line of production on the east and the highland on the west.

Production.—The chart (Fig. 11) shows graphically the history of Mexican petroleum production and the present tendency.

It will be noticed that the peak of production was reached in 1921, and since then there has been a steady decline. The decline can be attributed to several causes. The fact alone that over 1,250,000,000 barrels of oil have been extracted is itself evidence that at least locally many pools have been exhausted. The appearance of salt water in both Panuco and the South Field is further evidence that the old producing areas are nearing exhaustion. Already, since 1921, several companies have extensively resorted to "stripping" to prevent the too rapid rise of salt water in the vicinity of the wells.

Another factor that has caused the decline in production is the attitude of the government toward the oil companies. The burdens in the form of fines, taxes, and imposts are practically all the business as a whole can bear. Article 27 of the constitution provides that any titles to land

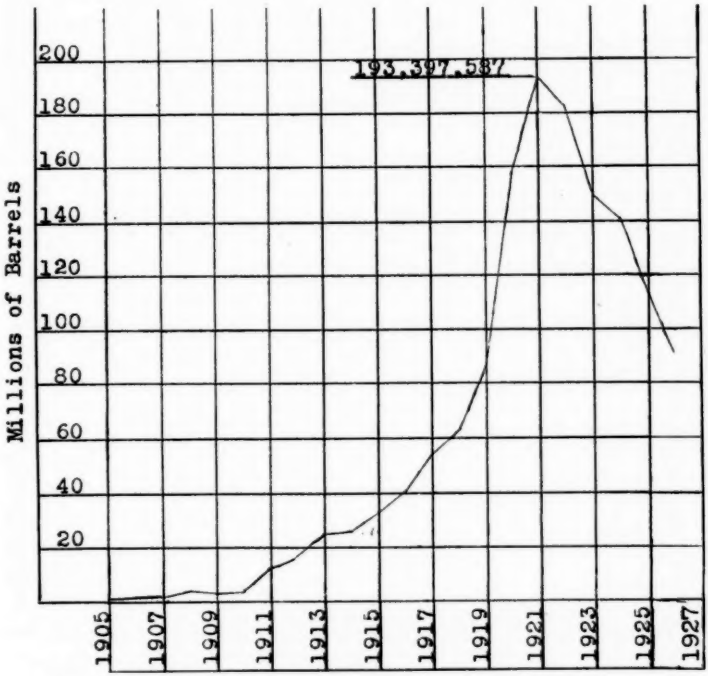


FIG. 11.—Graph showing Mexican production of petroleum in millions of barrels from 1905 to 1927. The 1927 production is based on Valentin R. Garfias' estimate of 63,000,000.

acquired subsequent to 1917 convey surface rights only, and that all mineral and oil rights remain the property of the government. This has been a deterring factor in explorational and developmental work.

A third factor in the decline of production has been the difficulties with labor. Several rather protracted strikes have for the time being stopped all production by the companies affected.

It is probable, however, that Mexico will be an important factor in

world-production for some years to come. This is indicated by the graph, even in case the proved areas only are worked.

It does not seem probable that the oil of Mexico is nearing a state of exhaustion except locally. A glance at a general map on which are plotted the areas that have produced the 1,250,000,000 barrels of oil suggests a curious condition if all the oil of Mexico were concentrated in two such relatively small areas.

In the event of more favorable conditions it is probable that new exploration and development will reveal new areas of production outside of the Panuco and South fields.

Origin.—There is little agreement among geologists as to the origin of the Tampico petroleum. It has been suggested that the Papagallos shales and even the overlying Tertiary Alazan shales were the source, and that the oil has migrated downward. This seems highly improbable considering the high pressure that would oppose such migration. Pressure of 1,500 pounds to the square inch is not uncommon in the South Field.

The general opinion seems to be that the Tamasopo limestone is not only the reservoir where the oil is now found, but also the formation that produced it. In spite of the wide popularity of this view, mature reflection seems to raise objections which, unless explained, would eliminate this lime belt as a possible source of petroleum. The conditions of sedimentation for the deposition of material that under proper conditions will result in limestone require deep water or at least sufficient distance from shore to prevent the admixture of land detritus. The broad extent of the Tamasopo limestone (p. 1185) and its high degree of purity are evidence of an open sea of equally broad dimensions. It is extremely doubtful that there is anywhere in the present seas sufficient rapidity of deposition of calcareous material to bury and preserve the fleshy parts of marine life that might in some future epoch produce petroleum. Without great rapidity of deposition any considerable preservation of flesh is impossible. Except in rare cases all animals die on the surface either as the prey of some predatory animal or through other natural agencies. In either case the flesh is eaten and only the hard calcareous parts are buried, with the result that there is but a shallow layer on the ocean floor where fleshy material is found, and this is living flesh.

Personal observation of the conditions of shore life along Puget Sound and at the Isthmus of Tehuantepec and at many intermediate points indicates that this living layer—or better, layer of living material—is about 2 feet thick, and so remains. As sediments are received this layer

simply rises. As the animals in the lower part of this layer die their flesh is eaten and the shells only accumulate.

It is doubtful if this layer is much thicker in the open sea; at any rate it is not of sufficient thickness to preserve in any considerable quantity the fleshy parts of animals. This, combined with the slowness of accumulation where the material for the sediments is extracted from the water itself, seems effectually to preclude a limestone from preserving organic material in quantities sufficient to account for the 1,250,000,000 barrels of petroleum that have been produced in the Tampico fields.

Another view that has some support is to the effect that the Lias shales were the source of the Tampico oil. Field observations indicate this to be the sounder view. Its black color and thinly bedded structure, beds of vegetal material, and beds of marine fauna indicate extensive swamp conditions with occasional submergences beneath a shallow sea. Three thousand feet of this organic shale is ample to produce the quantities of oil before mentioned.

Cummins,[1] in a semipopular article, has recorded an observation of great interest along this line:

> In the Jurassic where observed there are here and there thin seams of bituminous coal, but at other places there are seepages of oil from the Jurassic shales. At places there are globules of oil that can be seen under an ordinary magnifying glass, showing that the carbonization has not proceeded far enough to destroy the possibility of the shales being suitable as the mother formation for the oils of Mexico. . . . . The Jurassic is the probable source of the oil in the Mexican oil fields.

His conclusions seem well founded.

A few observations relative to the accumulation of vegetable material in swamps may be recorded at the risk of digressing too far afield if they succeed in throwing light on this as yet unsettled question. Soundings made in the semipeat beds that have accumulated in the basins of the glacial lakes in Washington have shown sphagnum moss 16 feet deep with chlorophyll and undecomposed moss at 22 feet, which was the bottom of the lake. Vegetation is now accumulating in the lakes that are not yet filled. In these latter there seems to be little or no decomposition taking place, and very little aquatic fauna. G. B. Rigg, of the University of Washington, is of the opinion that this condition is due to toxins that develop and prevent decomposition. The peat beds of Ireland and the large deposits of coal and carbonaceous material scattered through geological

[1] Cummins, *Pulse of Mexico*, August, 1923.

history from pre-Cambrian times on and the total lack of deposits of the fleshy parts of animals demonstrate that plant remains are preserved with great facility, in marked contrast with animal remains. That the organic compounds of plants are manyfold more stable than the carbon compounds of animal tissue is a fact that is too well known to require more than mention. It thus seems probable that the possibilities of animal remains of the Tamasopo seas being preserved in quantities sufficient to produce the Tampico oil are too remote for consideration. To urge this formation as the source seems particularly forced in view of the thick series of Liassic shale with an abundance of vegetal material that lies below.

RESULTS OF DISTILLATION AND OTHER STUDIES OF THE ORGANIC NATURE OF SOME MODERN SEDIMENTS[1]

PARKER D. TRASK[2]

The Scripps Institution of Oceanography of the University of California
La Jolla, California

ABSTRACT

A report of the first year's work on the American Petroleum Institute's research project on the "origin and environment of possible source beds of petroleum." In order to obtain a measure of the organic content of recent deposits from a number of different types of environments, so that possibly some one area may be found where possible "source beds" are actually accumulating today, the dried sediment is distilled in the same manner that oil shales are assayed. Of the forty-five samples that have been distilled to date, all types of sediment, ranging from sand to clay, yielded small amounts of oil. Recent deposits extracted with organic solvents gave but very small yields. Analyses of several different recent sediments show that the organic content in general varies directly with the fineness of grain, being low in sands and high in clays. Material from the bottoms of depressions in the sea floor of the Pacific Ocean west of Los Angeles and the Gulf of Maine seems to be richer in organic content than the adjacent shallower regions.

INTRODUCTION

This paper is the outcome of the first year's work on Project No. 4 of the American Petroleum Institute's research program. The object of the project is to study the conditions under which sediments that in the future may be source beds of petroleum are now accumulating. It relates to the solution of the question of the origin of oil, and it is hoped that it will furnish information of value to the petroleum geologist in his search for oil.

The project is supervised by a committee composed of W. A. J. M. van Waterschoot van der Gracht, chairman, T. Wayland Vaughan, and Austin H. Clark. David White and K. C. Heald are in close contact with the work. To all these gentlemen and to many others the writer is much

[1] This paper contains preliminary results of an investigation on "The Origin and Environment of Source Sediments," listed as Project 4 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by Mr. John D. Rockefeller. This fund is being administered by the Institute with the co-operation of the Central Petroleum Committee of the National Research Council. Manuscript received by the editor August 29, 1927.

[2] American Petroleum Institute, Research Associate.

indebted for guidance, aid, and criticism, as well as to the many petroleum companies, governmental bureaus, and institutions which without fail have enthusiastically assisted and co-operated with those in charge of the project and have materially advanced its cause.

In attacking the problem it was necessary, first, to select methods and apparatus, particularly to devise suitable instruments to collect sediments; second, to discover what sediments may be possible source beds of petroleum; and third, to find some advantageous region in which to make extended studies of (1) the conditions under which such source beds are being deposited, (2) the detailed nature of the deposits, and (3) the various changes that may be caused during deposition and in the course of time by different physical, chemical, or biological agencies.

The work to date has been confined to these preliminary problems. Two bottom samplers[1] have been constructed; experiments have been made to determine the most suitable means of obtaining an index of the organic content of sediments, particularly with reference to their oil-forming abilities, thus giving a measure of their possibilities as source beds; and a rapid reconnaissance of regions where different types of sediments are accumulating today was undertaken in an effort to find possibly one area where "source beds" are now being deposited, with the intent of studying later that area in detail. In the course of such a reconnaissance it was hoped that information as to the general distribution of organic matter in sediments and how the organic content varies in different types of deposits would be obtained.

Considerable progress has been made on this survey. Since so many of the source beds of the present-day oil fields seem to be marine in origin, attention was concentrated on marine environments. Samples have been collected from the Gulf of Venezuela, the best available example of a tropical epi-continental sea; Lake Maracaibo, a tropical brackish-water lagoon; the Orinoco Delta, a delta the present-day deposits of which represent practically normal conditions unaffected by the advent of man and civilization (in contrast to the present highly abnormal deposits of the Mississippi Delta); the limestone-forming regions of Florida and southern Cuba; Pamlico Sound and the estuary of the Potomac, brackish-water areas in a temperate region; the lagoons of south Texas, of which Baffin Bay represents in a semiarid country a concentration basin that has a restricted connection with the sea; Great Salt Lake; and the Pacific Ocean near Los Angeles, the floor of which is very uneven and

[1] P. D. Trask, "Oceanography and Oil Deposits," *Trans. Amer. Geophys. Union, National Res. Council. Bull. No. 61* (1927), pp. 235–40.

contains several basin-like depressions. The analyses of these sediments are now in progress and further collections are in prospect, particularly from the Pacific Coast.

DISTILLATION OF SEDIMENTS

Destructive distillation of the dried sediment in the same manner that oil shales are assayed was selected as being the most practicable means of determining an index of the organic content; and in addition it affords comparisons with distillation of oil shale, thus shedding light on the changes undergone in sediments from time of formation until the ultimate rock product is reached. Extraction with solvents was given up because of the very small yield, the seventeen samples collected from the Pacific Coast averaging but 0.06 per cent. Ignition tests, although occasionally misleading due to unobserved high calcium carbonate content, because of their rapidity were found to be a convenient guide to the selection of samples to be distilled.

Procedure.—Before distilling, the samples were dried at a temperature of 55°–60° C., and then ground to a powder. They were then distilled in one-half-pint iron retorts, using gas as a source of heat, as described by Karrick[1] in his manual on testing methods for oil shale, except that no manometer was used. A few samples were run in an electric furnace. In view of the effect of different rates of heating on the type and quantity of oil produced, all tests were run as nearly alike as possible. The temperature was determined by a thermocouple placed in an iron well that extended into the center of the retort. The samples were distilled from 3.5 to 4 hours. The temperature reached 350° C. after one hour, increased about 2° a minute up to 600°, and was then raised rapidly to 700° C., which as a rule was the final temperature attained.

The first product given off was water, which was formed copiously up to a temperature of 150° or 200° C. Following this, a strong phenol odor was produced which continued to the end of the experiment. With the exception of sandy samples, oil began to form, as a rule, between 350° and 425° C. and continued to 500°–575° C., although wide variation existed in the temperatures between which oil was produced in individual samples. The maximum temperature of oil production in reality may be considerably less than 575°, as the thermocouple measuring the temperature was located in the lower part of the retort, and the overlying material might have been somewhat cooler. If comparisons be made with

[1] L. C. Karrick, "Manual of Testing Methods for Oil Shale and Shale Oil," *U. S. Bureau of Mines Bull. 249* (1926), pp. 6 ff.

Karrick's[1] work in which he measured the temperature of the charge in the retort at four different places, the temperature in the coolest part of the retort used in our tests may have been 50° or 75° C. less than indicated by the pyrometer.

In addition to the production of oil, a black, flocculent precipitate was formed, which when first produced pervaded the entire distillate, but in the course of an hour settled to the bottom. It perhaps should be called more properly the "heavier black flocculent portion of the distillate," rather than a precipitate, but it is conveniently referred to as a precipitate. Its temperature of formation was the same as that for the oil, but in individual samples the temperatures between which, and the rate at which, it was produced did not correspond to the oil production.

Clear drops of a watery fluid in many samples were produced up to the final temperature of 700° C., and were still forming at 900° C. in one sample. It is likely that this fluid is largely water from hydrous minerals. The intermediate watery layer between the black precipitate at the bottom and the oil on top in general was of a lemon-straw color. However, in a few tests its color was amber, in others cherry, and in sandy samples, green, a color not observed in the distillate from the silts or clays.

In view of the fact that the distillation test is used primarily to obtain an index of the organic content of sediments, and since the chief object of work at this stage of the problem is to find what is the organic content of deposits from a variety of places, time has not yet been taken to study in detail the products yielded on distillation.

Results of distillation.—To date forty-five samples, all from one region, Pamlico Sound,[2] have been distilled. Although all types of sediment from clay to sand were tried out, this work serves only as a preliminary test of the method, and does not warrant making definite inferences until deposits from other types of environment have been analyzed in the same way. In running the distillations, although it was not possible in every case to use a charge of 240 grams of dried sediment, all results have been corrected to that base, so that each cubic centimeter of fluid obtained would be the equivalent of one gallon per ton.

1. The most important result is that, with possibly one exception, every sample yielded oil, although the production from sands and a few of the silts was so low as to be practically negligible.

2. In no sample was the quantity of oil high, 2.7 gallons per ton being

[1] *Op. cit.*, p. 13.

[2] Opportunity to collect samples was extended by U. S. Bureau of Fisheries and North Carolina Fish Commission.

the highest yield obtained.[1] This is very low compared with the better grades of oil shale, which produce 30–60 or even more gallons per ton.

3. It is surprising that 2.7 gallons per ton should have been the highest yield procured, but until the reconnaissance of typical environments is farther along, comparative data to determine whether or not the Pamlico muds are good potential source beds are lacking. They may be found to be very poor; but on the other hand the place of a higher yield of oil may be occupied by the black precipitate that gathered in the bottom of the distillate. The amount of this precipitate varied with the organic content

TABLE I

COMPILATION OF RESULTS OF DISTILLATION OF FORTY-FIVE BOTTOM SAMPLES FROM PAMLICO SOUND

TYPE OF SEDIMENT	PERCENTAGE OF LOSS BY IGNITION			OIL YIELD (GALS. PER TON)			BLACK PRECIPITATE (GALS. PER TON)			TEMPERATURE FIRST DROP OF OIL		
	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.
Sand	0.9	1.9	4.0	0.0?	0.1	0.4	0	0	Tr.	450	488	500
Siltlike	3.2	5.7	7.5	0.05	0.6	2.4	0	1.5	4.5	370	400	480
Claylike	7.7	12.4	16.0	0.4	1.7	2.7	1	7.1	14	350	375	415

and reached a maximum of 14 gallons per ton, although part of this volume may be due to water in which the precipitate was suspended.

4. The temperature of formation of the oil ranged between 350° and 575° C., a range comparable with that obtained from the distillation of oil shales. As seen from Table I, the temperature at which the first drop of oil was produced from the sands was about 100° C. higher than from the silts or clays. Furthermore, this temperature of initial oil production varied widely in different samples of clay and silt.

5. At least two types of oil were produced: more commonly a dark brown, almost black, oil, and occasionally an amber oil. However, it is probable that other kinds were formed also.

6. The amount of oil produced varied directly with the loss by ignition and showed that the ignition loss was a good index of the organic

[1] Mention should be made here of Jun-ichi Takahashi's admirable work on "The Marine Kerogen Shales of Japan," published in the *Science Reports of Tohuko Imperial University*, Series III, Vol. 1, No. 2, pp. 53–156, particularly pp. 82 and 136, in which he reports a yield of 0.19 per cent oil (approximately 0.5 gallons per ton) upon distillation of modern sediments from Kahoku Lagoon. However, as he used a method different from that just described, it is difficult to make comparisons. He also discusses the action of solvents on recent sediments (see pp. 136–42, and *Economic Geology*, Vol. 22 (1927), p. 146.

content of the sediment, although of course subject to some error because of varying amounts of non-organic volatile material driven off from different samples.

7. As shown by Table I, several features vary directly with the fineness of the sediment. The determination of type of sediment is based on hand-lens determination unsupported by mechanical analyses, and indicates relative degree of fineness of texture. The "clays" are in reality probably silts. Also the maxima and minima in the various columns, as a rule, come from different samples.

EXPERIMENTS WITH SOLVENTS

General remarks.—The action of solvents was tested on a suite of sediments collected at different depths, some as great as 1,000 meters, in the Pacific Ocean near Los Angeles.[1] The samples were obtained with a clam-shell snapper that had a capacity of about 300 cubic centimeters. Except for the sandy deposits in relatively shallow water, the sediments had a peculiar green color, a soft unctuous consistency, and no odor of hydrogen sulphide. After bringing them to the surface, to inhibit bacterial decay, they were placed in air-tight pint fruit jars and kept in a brine bath at approximately 0° C. until the return to the laboratory, where they were weighed in their moist condition, dried at 75° C., and weighed again to find approximately the percentage of water they held in their natural condition. As is seen from Table II, column 3, this was found to vary directly with the fineness of the sediment, being low in sands and high in clays. After drying, part of the sediment was pulverized and subjected to ignition and kjeldahl nitrogen tests.

Extraction tests.—After preliminary experiments to find the most feasible procedure the samples were extracted with a mixture of two parts, 95 per cent ethyl alcohol and one part ether (over sodium).[2] Each sample was extracted for an hour in a flask immersed in a water bath that had a temperature of about 45° C., the flask being shaken vigorously at intervals; and after pouring off the extract, the residue was extracted overnight with a fresh alcohol-ether mixture. The combined extracts were dried and taken up with ether to eradicate the inorganic salts, chiefly sodium chloride, dissolved by the alcohol, and were then saponified with alcoholic potash. The saponifiable portion is expressed as fatty acid throughout the paper.

[1] Opportunity to collect and analyze samples was extended through courtesy of Scripps Institution of Oceanography.

[2] Material analyzed in the chemical laboratory of Stanford University, through the courtesy, and under the advice, of Professors C. L. Alsberg and R. E. Swain.

TABLE II

DATA ON TESTS MADE ON SAMPLES COLLECTED FROM THE PACIFIC OCEAN NEAR LOS ANGELES

1	2	3	4	5	6	7	8	9	10	11	12
1....	2252	56.5	10.0	.215	2.15	.014	.021	33°15.8′	117°43.5′	740	10 Capistrano
2....	262	54.8	10.2	.230	2.25	.015	.055	33°56.3′	118°44.6′	540	5 Sta. Monica
5....	153	60.2	19.6	.361	1.80	.036	.093	33°48.2′	119°20.0′	995	21 Hueneme
6....	262	52.6	8.8	.173	1.97	.020	.041	33°57.0′	119°17.5′	765	12 Hueneme
8....	164	66.0	15.7	.335	2.13	.059	.095	34°11.2′	119°57.6′	550	14 Sta. Barbara
10....	64	63.5	13.5	.327	2.42	.035	.049	34°15.5′	120°14.5′	490	13 Sta. Barbara
11....	5321	32.6	4.5	.074	1.64	.051	.047	34°22.8′	120°22.3′	186	5 Sta. Barbara
13....	1352	49.0	7.8	.182	2.33	.025	.017	34°20.5′	120°22.8′	290	7 Sta. Barbara
15....	115111	32.8	11.1	.065	0.59	.021	.017	33°57.5′	119°54.3′	280	3 Sta. Cruz Id.
16....	163	56.1	12.1	.276	2.27	.029	.034	34°14.7′	119°49.8′	376	10 Sta. Barbara
18....	262	56.1	6.2	.089	1.44	.028	.020	34°14.0′	119°28.5′	70	7 Sta. Barbara
20....	163	64.2	12.9	.262	2.03	.022	.029	33°55.6′	118°51.0′	789	5 Pt. Dume
21....	163	58.6	11.8	.256	2.17	.030	.030	33°56.2′	118°50.3′	685	4 Pt. Dume
24....	Sandy	29.5	3.2	.053	1.66	.008	.012	33°59.4′	118°51.4′	180	3 Pt. Dume
25....	2441	41.9	6.7	.132	1.97	.008	.017	33°59.1′	118°48.4′	385	1 Pt. Dume
26....	352	46.0	8.8	.191	2.17	.017	.018	33°54.5′	118°40.0′	358	7 Sta. Monica
27....	1531	45.9	7.3	.164	2.24	.021	.027	32°53.3′	117°21.0′	320	5 La Jolla
Av...	1252	51.0	10.0	.199	1.95	.026	.037	.....	.....	470	7.6

Column 1, number of sample.
Column 2, classification of sample as based on mechanical analyses made by U. S. Bureau of Soils.*
Column 3, approximate percentage of water in sediment in natural state.
Column 4, ignition loss. Average of two tests.
Column 5, organic (kjeldahl) nitrogen. More than half done in duplicate. All samples deviating markedly from average, done in duplicate.

* In view of the fact that sediments as classified by mechanical analyses consist of several variables, that is, several different sizes of grain, it is very difficult to portray adequately the nature of a sediment by a symbol or series of words. The plan adopted here is to assign a digit corresponding to the tens of per cent of each of the sizes of grain present. Anything larger than 4.0 per cent would be represented by the next higher digit. Thus both 14.0 and 23.9 would be classified by the digit 2. The digit farthest to the right represents the amount of clay present. If the amount of clay is less than 4.0 per cent a zero is used so that the figure farthest to the right will always represent a clay, but zeros to the left of the first integer are omitted. Thus, reading from the right, the first digit represents clay, the second silt, the third very fine sand, etc.

Table III shows the detailed analysis of sample 1, Table II. It has less than 4 per cent of each of the three coarser grades of sand, which, being to the left of the first integer, are omitted, its classification being 2252. The second sample, Table III, has three of its seven sizes of grain less than 4 per cent. The two zeros to the right of the first integer must be used, but the one to the left is omitted, its symbol being 320320.

TABLE III

BASIS OF MECHANICAL CLASSIFICATION OF SEDIMENTS USED IN TABLE II

	Fine Gravel 2–1 mm.	Coarse Sand 1–.5 mm.	Medium Sand .5–.25 mm.	Fine Sand .25–.1 mm.	Very Fine Sand .1–.05 mm.	Silt .05–.005 mm.	Clay .005–0	Symbol
Sample 1, Table II	.1	.3	.3	17.1	15.3	48.1	19.1	2252
A sample.....	3.1	32.4	16.2	3.8	25.6	16.2	2.7	320320

Column 6, column 5 divided by column 4×100 to give an approximation of percentage of organic matter as nitrogen.
Column 7, unsaponifiable alcohol-ether extract.
Column 8, saponifiable alcohol-ether extract, that is, fatty acid.
Column 9, latitude of station.
Column 10, longitude of station.
Column 11, depth of water in meters.
Column 12, approximate distance in nautical miles from mainland. Geographic name gives general location, not point from which distance was measured. Sample 15 occurs between Sta. Cruz and Sta. Rosa Islands.

Each sample produced a small but measurable quantity of fatty acid and unsaponifiable material, as may be seen from Table II, columns 7 and 8. In these samples the fatty acid and unsaponifiable extract averaged 0.037 and 0.026 per cent, respectively, of the whole sample; or, assuming the ignition loss to represent the organic content of the sediment, the quantities of these substances are respectively 0.37 and 0.28 per cent of the organic matter.

The total quantity of fatty acid in the sediment was probably not obtained, as more extended extraction would doubtless have yielded more material, and also possibly some of the fatty acid may have been in the form of calcium and magnesium soaps, which would not be extracted with ether. Nevertheless, as identically the same thing was done to all the samples, the results are at least roughly comparable.

VALUE OF IGNITION TESTS

One of the striking features brought out by these experiments is the accord of the ignition test with the several other means of determining the organic content. Some doubt existed at the beginning of the work as to the effect of water held by colloidal adsorption, hydrous and volatilizing minerals, and carbonate content upon the value of this test. In discussing the distillation results on page 1224 the parallelism between the ignition loss and the amounts of oil and black precipitate produced has already been mentioned. Similarly, the results of the nitrogen determinations shown in Table II, columns 5 and 6, demonstrate this accordance. The percentage of organic nitrogen occurring in organic matter is not constant, but as a rule it does not vary widely in any one particular type of life, such as plankton; consequently it may be used as a rough index of the amount of organic matter present.

Column 5, Table II, shows the percentage of nitrogen of the entire sediment, but column 6 represents a ratio obtained by dividing this percentage of nitrogen by the ignition loss in order to approximate better the percentage of the organic matter present as nitrogen, assuming the ignition loss to be a measure of the organic content of the sediment. If the ignition loss is not a measure of the organic content, then the ratios

obtained thus should vary widely; but they do not (except for sample 15, which contained several shell fragments). Consequently it seems that except for carbonate-rich sediments, in general, considerable faith may be placed in the ignition test as a rough index of the organic content, but of course not as a quantitative determination of the amount.

GEOLOGIC INTERPRETATION OF RESULTS

Distillation tests.—As the project is scarcely out of its preliminary stages, sufficient material to substantiate general inferences has not yet been obtained. Perhaps the most impressive feature of the work is the practically universal production of small amounts of oil from all types of sediment, from clay to sand, that have been studied; but the interpretation of how this fits in geologically should be postponed until the reconnaissance covering a large number of environments has been completed.

Pacific Ocean region near Los Angeles.—The area occupied by the Channel Islands near Los Angeles is interesting in that it has a very uneven bottom, apparently consisting of a series of up- and down-thrown blocks. Except for its perhaps less insular or landlocked condition and possibly greater depth, it resembles somewhat the conditions that existed in the Los Angeles Basin, a few miles to the east, during the Miocene and Pliocene, when the material for the present rich oil deposits was laid down.

Although too few samples were taken to base definite inferences upon them, and no distillations were made, it is very striking that the highest yield of organic matter was found in the two depressions in the sea floor from which samples were obtained. Sample 5, Table II, was collected in 1,000 meters of water on the flank of a deep depression south of Anacapa Island. The ignition loss was 19.6 per cent and the organic nitrogen content 0.36 per cent, the highest yield from any of the samples. Samples 8 and 10 were taken from the deepest part of the Santa Barbara Channel between the mainland and Santa Rosa Island. The ignition losses were 15.7 and 13.5 per cent, respectively, and the total nitrogen, 0.34 and 0.33 per cent. Sample 16, collected on the flanks of this depression, shows somewhat lower values. Sample 6, although taken in 789 meters of water, occurs on a hump between two depressions, and has relatively low ignition loss and organic nitrogen content compared with sample 5 from the depression to the south, namely, 8.8 and .17 per cent, respectively. Samples 20 and 21, procured from the lower parts of the shoreward slope of a depression, are also relatively high in organic nitrogen and ignition loss.

Likewise, ignition tests made on samples collected by W. S. Burbank in the Gulf of Maine, the topography of the bottom of which is irregular

and contains basins similar to, but shallower than, the Channel Islands region, suggest a corresponding increase in organic content of the sediments toward the depressions.

Pamlico Sound.—Samples from some eighty different localities over the entire extent of Pamlico Sound, North Carolina, were collected for the most part with the modified Ekman sampler,[1] which brought up a core as a rule 75 centimeters long. The water is shallow and is characterized by many bars and shoals of sand, the organic content of which, as measured by ignition and distillation tests, is much less than that of the mud that occupies the broad intervening areas, which are from 17 to 24 feet deep. The ignition loss is much higher in the mud portions at the west end of the sound and in the center of some of the embayments called rivers, such as Pamlico and Neuse rivers, than it is in the mud districts in the central and eastern portions of the sound, running about 12 per cent in the former and 6 in the latter. This is correlated with the texture of the deposits, as the sediments in the Pamlico-Neuse River district are considerably more fine-grained than in other parts of the sound.[2] The water is approximately the same depth in the two regions and the presence of hydrogen sulphide odor in the muds is characteristic.

Evidently no difference in ignition loss takes place at depth in the deposit, at least down to 75 centimeters (2.5 feet), for in practically all samples essentially no change occurred from top to bottom. Only a few deep samples were taken, but in one 23 feet deep the ignition loss averaged 12 per cent from the surface to a depth of 20 feet, where it increased to 16 per cent. The ignition loss of another sample ranged around 7 per cent from the surface to a depth of 10 feet, below which it increased to 12 per cent. On the other hand, a third sample was practically uniform throughout its whole depth of 15 feet.

Relation of organic content to fineness of grain.—In concluding, mention is made of the striking confirmation, brought out by the work to date, of the theory that the amount of organic material in sediments varies with the texture. As seen by tables I and II, the amount of oil yielded on distillation, the amount of black precipitate produced, the ignition loss, the nitrogen content, and, to a lesser degree, even the fatty acid content—each more or less a measure of the organic content—all, in practically every sample, vary directly with the fineness of grain, being low in sands and high in clays.

[1] P. D. Trask, *op. cit.*, p. 238.

[2] Oral communication from H. R. Seiwell, who has worked extensively in Pamlico Sound.

GEOLOGICAL NOTES

CAPACITY OF PIPE

Geologists and scouts often have occasion to compute the amount of oil or other fluid in a given amount of open hole, casing, or pipe line. To obtain the amount many of them go through rather laborious calculations that may be avoided by remembering the following simple rule: *The capacity (in barrels) of a thousand feet of pipe is equal to the square of the internal diameter (in inches).*

The foregoing formula gives a result less than 3 per cent too large, an error that may usually be neglected in the calculations. If desired, the answer may be corrected by subtracting 3 per cent. A four-inch (internal diameter) pipe contains 15.54 barrels per thousand lineal feet. By the approximate formula here given the result would have been 16 barrels, or with the 3 per cent correction, 15.52 barrels.

JOHN H. WILSON

GOLDEN, COLORADO
September 12, 1927

DISCUSSION

"EPI-ANTICLINAL" FAULTS

It is pleasant in science, in these days of relativity and of the perhaps too critical examination of the fundamental postulates of mechanics, to find in the literature a statement of finality, a solid truth with no "probablys" or "possiblys" attached to it. It is therefore with a certain relief that one turns to the fifth and last conclusion, the conclusion of the conclusions, to a recent article in this *Bulletin*, "The Origin and Significance of 'Epi-Anticlinal' Faults as Revealed by Experiments,"[1] by Theodore A. Link. The conclusion reads:

> Therefore, since the structures east of the Rocky Mountains exhibit tension fissures or "epi-anticlinal" faults converging approximately toward the west, *it must* be concluded that the *stresses* which caused the building of the Rocky Mountains *must* have acted from the west, and that *all theories regarding this orogeny which postulate stresses from the east must be discarded as untenable.*

Italics are by the present writer.

This is very interesting. If the experimenter had placed the buffer of his apparatus against the wall or a post and had forced the containing box against the buffer, so that the "active stress" was applied from the side of the toy anticline, he would doubtless have written with equal cogency and certitude that "all theories regarding this orogeny [of the Rocky Mountains] which postulate stresses from the *west* must be discarded as untenable."

One might then have the temerity to suggest with Major William Bowie[2] that the continued burial of the western Great Plains during Cretaceous and Tertiary times, with the consequent increase in depth, heating, and *expansion* due to the heating of the underlying terrain *may* have caused a thrust from the *east* active in "this orogeny" of the Rockies.

In other words, Mr. Link has totally neglected a consideration of the time-honored adage of mechanics that "action and reaction are equal," which is a fair generalization in a truism. If the two senses of an applied force are opposite in the same straight line there is no difference whatever in the magnitude of the force in each sense, whether there be uniform movement, no movement, or acceleration. Further, *such a closed system can furnish no clue as to the ulterior origin of the forces acting on it from the outside.* Students of tectonics would do well to get these ideas thoroughly grounded, for their misconception, or lack of conception, has led to serious blunders both in the classroom and in the field.

[1] *Op. cit.*, Vol. II, No. 8 (1927), pp. 853–66.

[2] In charge of the Division of Geodesy, U. S. Coast and Geodetic Survey. Personal communication.

As another point it might be well to call attention to the use of the word "stress." Stress is force per unit area, as ordinarily used in engineering terminology. It is not synonymous with "force"; but it seems to be so used in the article under discussion, for example, on page 853: "A cube of building stone unsupported on four sides and subjected to compressive *stresses* will fracture along planes inclined to the axis of maximum *stress*." (As a matter of fact the rock tends to break in the surfaces of maximum force which is a shearing force. See any standard text on the mechanics of materials.) And again (on pp. 852–54): "Plunging anticlines are not, in most cases, the result of *active stresses* from four opposing directions, but owe their existence to a maximum *active pressure* from one, and in some cases, two opposing sides, and a lateral diminution of such *stresses*." And so on through the article.

One notes in passing that "four opposing directions" is an impossible situation; there can be only two opposing directions. And *pari passu*, there cannot be one direction of maximum force, or "active pressure"; there must be, by the adage previously cited, two opposing directions of equal (and opposite) maximum forces.

One is puzzled about the expression "active stress." A force may be defined as an action which produces or tends to produce acceleration or change of momentum; it is measured, in Newtonian mechanics, by the time rate of change (or time derivative) of the momentum of a free body of known mass. So a force *acts*, per se; that is, it is *active* if it exists at all. "Active stress" and "active pressure" are, therefore, in a sense, redundant expressions. One assumes that by "active stress" is meant "applied force."

On page 854 one reads: "The actual *relief of stresses* was therefore not alone upward but also toward the sides of the apparatus." The expression "relief of stresses" is quite devoid of any precise meaning, though one may guess at it. Perhaps "the actual *directions of deformation* were therefore not alone upward, etc.," will express the idea it was intended to convey.

The latter part of the present discussion is not a quibble on words. It is sufficiently evident that words are symbols, which, as our thought becomes more precise and exacting, gradually crystallize by convention to inclose rather definite concepts. Unless geologists learn to use engineering, mechanical, and chemical terms correctly their research along these lines must remain of doubtful value. It will always be open to a lingering suspicion of loose thinking.

In conclusion, the actual experimental results obtained by Mr. Link in the geophysical laboratory of the University of Chicago are informing and apropos. They doubtless have significance in the origin of epi-anticlinal faults. Nevertheless, one feels distinctly that, in spite of the definite assurance to the contrary, the field of Rocky Mountain tectonics is still an open one.

D. F. HIGGINS

LOVELAND, COLORADO
September 17, 1927

PROBLEMS OF THE CHUGWATER-SUNDANCE CONTACT

Brainerd and Keyte (this *Bulletin*, Vol. 11, No. 7) call attention to the confusion in some of the older literature, and very likely in the minds of some of the students of Rocky Mountain stratigraphy, of several distinct sets of red beds of Triassic and Jurassic age. Some additional points which may be brought out in connection with this topic are here briefly discussed.

It is shown by the ammonites[1] that the Ellis formation is in large part older than the Sundance formation. Some overlap in time might well be expected, though no positive evidence of it has yet been produced. Any argument as to an unconformity in the midst of the Sundance based on the overlap of Ellis on older beds would not stand. In the San Rafael Swell, Utah, there are two marine zones of Sundance age separated by red beds, and the suggestion of a similar situation in Wyoming is strong. Any single erosion interval in this sequence would not seem to be important. The writers doubt that the variation cited by Brainerd and Keyte in thickness of the lower Sundance is to be explained by major erosion on the plane indicated.

The Alcova limestone, cited as equivalent to the lower fossiliferous zone of the Sundance, certainly has nothing to do with it. The Alcova limestone, as shown by Dr. Lee's posthumous correlation paper,[2] is to be considered marine Lower Triassic. Above it come beds that correspond to the Upper Triassic Jelm formation and "Popo Agie beds," then an unconformable, tangentially cross-bedded sandstone, and then the lower fossil zone of the Sundance.

The most convenient and certainly the most logical place to draw the base of the Sundance over a large part of central and southern Wyoming is at the base of the cross-bedded sandstone. There is much reason to believe that this sandstone is a direct correlative of the Nugget sandstone of the eastern Uintas and possibly of the Navajo sandstone of the plateau region.

It is the writers' belief that there are four units in the red beds of central Wyoming: (1) a lowermost unit of interbedded Permian marine limestones and red beds, which westward and northward become the Embar and Phosphoria formations; (2) a Lower Triassic unit of chiefly marine origin, essentially equivalent to the Moenkopi formation of Utah, including the greater part of the Chugwater of various authors with the Alcova limestone member at or just below the top and passing in part into the Dinwoody formation; (3) an Upper Triassic unit of non-marine origin, including the Jelm formation and the "Popo Agie beds" and essentially equivalent to the Chinle formation of the plateau country; and (4) an Upper Jurassic unit of marine origin in the Sundance formation. The separation of the two lower units is not very sharp at some places, though at others the presence of the Permian limestones affords a basis for it; the second

[1] J. B. Reeside, Jr., "Some American Jurassic Ammonites," *U. S. Geol. Survey Prof. Paper 118* (1919), and unpublished data.

[2] W. T. Lee, "Correlation of Geologic Formations between East-Central Colorado, Central Wyoming, and Southern Montana," *U. S. Geol. Survey Prof. Paper 149* (1927).

and third are usually distinct; the fourth lies above persistent distinctive beds, generally non-red.

The presence of red strata in the marine Jurassic of the Rocky Mountain region has been on record for some time, especially in Utah,[1] though no doubt many geologists have overlooked it, and it is well that the fact is again brought forward.

C. E. DOBBIN
J. B. REESIDE, JR.

U. S. GEOLOGICAL SURVEY
WASHINGTON, D.C.
September, 1927

CORRECTION

The titles printed under Figures 2 and 3 of the article by C. R. Thomas on "Flank Production of the Nemaha Mountains (Granite Ridge), Kansas," in the September *Bulletin*, pages 923 and 925, should be reversed. Figure 2 shows the structure on the Ordovician and Figure 3 shows the structure on the Lansing.

The following corrections should be made in papers by Sidney Powers in the October *Bulletin:* p. 1108, seventh line from end should read, " . . . Glenn pool, the last of the great lens fields before Burbank"; p. 1112, eighth line should read, " . . . Blaine gypsum of Amarillo (300 feet below the alibates dolomite)."

[1] W. B. Emery, "The Green River Desert Section," *Amer. Jour. Sci.* (4th ser., 1918), Vol. 46, pp. 568–70.

J. B. Reeside, Jr., "Notes on the Geology of Green River Valley," *U. S. Geol. Survey Prof. Paper 132* (1923), p. 45.

REVIEWS AND NEW PUBLICATIONS

Geologisches Praktikum. By Rudolf Sokol. Gebrüder Borntraeger, Berlin, 1927. 127 illus. 248 pp. Price, M. 14.50.

Sokol's *Geologisches Praktikum* is written for use in the classroom and for beginners in the field. Experienced field geologists are acquainted with most of its contents, but the student versed in the German language can learn much from it. Teachers will also be interested on account of the arrangement of the contents and the lists of problems, which they can work out with their students. The contents range from explanations in reading maps, and in measuring strike and dip, to a detailed discussion of faults and methods of constructing their trace on different planes, which is important in mining. There is a key for determination of igneous rocks in the field, also a short but very clear outline of geophysical methods. Unfortunately the author was not acquainted with the very recent results of geophysically locating oil fields. The possibility of underground mining of oil is mentioned, but not the successful oil-mining operations in Europe.

Edward Bloesch

Tulsa, Oklahoma
September 7, 1927

Oil and Retortable Materials. By George W. Halse. Chas. Griffin & Company, Ltd., London, and J. B. Lippincott Company, Philadelphia, 1927. 2 plates. vi+146 pp. Price, $4.00.

After a brief historical sketch of the development of fuels (Chap. 1), Halse describes the mode of formation of coal, its characteristics and distribution (Chap. 2). Under the caption "Torbanites and Cannels" he describes these two materials and their occurrence, following E. H. Cunningham Craig's idea that torbanite occupies an intermediate stage between coal and petroleum and that torbanite owes its character to the fact that its ash is a colloidal material similar to Fuller's earth which has adsorbed minute drops of petroleum as they were made from the uncarbonized vegetation. He states that the relative unimportance of torbanites and cannels for oil production is due to the lenticular and local character of the deposits.

Oil shales he defines as colloidal clay with adsorbed petroleum and states that the removal of the adsorbed organic matter which has been termed "Kerogen," together with the absorbed portion, is the object in view in the retorting of oil shales.

In Chapter 5 the author gives not only a classification of fuels but shows the distribution and probable amount of each in different countries.

In Chapter 6, after giving a historical sketch of the development of retorting in the manufacture of liquid fuel and gas, he discusses the effect of gradual heating, quick removal of the gases, continuous operation, temperature control, and dust and plastic condition of material, on the products evolved in the distillation process.

A rather complete description of the products of low-temperature distillation of oil shales, cannel coals, torbanites, bituminous coals, lignites, and brown coals follows.

Finally the author devotes a few pages to a discussion of the future sources of supply of liquid fuels of the world, and of England in particular.

DEAN E. WINCHESTER

DENVER, COLORADO
September 10, 1927

Observations on the Geology of the Santa Elena Peninsula, Ecuador, South America. BY GEORGE SHEPPARD. *Jour. Inst. Petrol. Tech.*, Vol. 13, No. 62 (June, 1927), Pp. 424–46, with 5 sketch maps, 2 figs., and 9 photos in text.

The area dealt with in this paper is the most westerly headland of the coast of Ecuador, located about 2° south of the equator. Such papers as have previously been published about it (of which a bibliography is attached) indicate that it is an area of considerable interest, both scientific and commercial; and this is confirmed by the present communication.

The preservation of the peninsula is due to a backbone of resistant chert, into which igneous dykes are intruded. These dykes are probably differential offshoots of a deeper-seated igneous mass forced to the surface along planes of dislocation. The author, contrary to some previous authorities, considers the cherts to be sediments of lower Tertiary age which have been silicified by pneumatolytic action at the time the dykes were intruded. This was probably in post-Tertiary times, when a period of intense tectonic compression of the area occurred.

To the southeast, near Ancon, comparatively unaltered deltaic and estuarine beds of Eocene and Oligocene age occur, which, compared to Peru, are remarkably unfossiliferous. The much-discussed "Ancon Clay-Pebble Bed" occurs here, in the matrix of which clay pebbles, a few foreign boulders and blocks of denuded sandstone are imbedded. The author considers that it was formed by the denudation of an Eocene land surface under abnormal climatic conditions. Such folds as may have occurred in this area are now obliterated by step-faulting and probably overthrusting and now appear as a series of irregular faulted blocks.

The occurrence of oil in this area has attracted interest for a long time. The earliest oil industry was centered in the Santa Elena Peninsula, where a thick

inspissated oil is extracted from shallow pits. The oil migrated upward through the chert from a deeper oil-bearing horizon (probably Eocene) along passages caused by the igneous intrusions and shatter-belts.

The Ancon area has more recently attracted attention. The oil sands are of upper Eocene and Oligocene age, and deep wells have been drilled to exploit them. The oil was probably concentrated by a monoclinal fold prior to the post-Tertiary shattering of the beds. The author considers that here the upper Eocene shales are the source of the oil.

A 6,000-foot well drilled considerably east of this area on a Miocene structure found no oil or gas.

A final note on the local mud volcanoes and hot springs concludes the paper.

F. W. PENNY

TULSA, OKLAHOMA
September, 1927

ABSTRACT

Geology of Alabama. BY EUGENE A. SMITH. *Geological Survey of Alabama, Special Report 14.* University, Alabama, 1927. 312 pp. Price, $1.65, postpaid.

The book is divided into four parts: "The Crystalline Rocks," by George I. Adams; "The Paleozoic Rocks," by Charles Butts; "The Mesozoic Rocks," by L. W. Stephenson; and "The Cenozoic Formations," by C. Wythe Cooke.

The state is broadly divided into two physiographic divisions, the Atlantic Coastal Plain occupying the southwestern three-fifths of the state, and the Piedmont Upland, the Appalachian Valley, the Appalachian Plateaus, and a small area of the Interior Lowlands making up the northeastern two-fifths. The subdivisions last named enter the state in belts from the northeast, following the trend of their structures. The southeastern of these belts, the Piedmont Upland, is made up of metamorphic and igneous rocks of the pre-Cambrian and some metamorphics of the Paleozoic. The Appalachian Valley is of folded Paleozoics, the Appalachian Plateaus of gently dipping or warped Paleozoics, and the Interior Lowlands of very broadly warped and deeply eroded rocks of the same system. The Coastal Plain sediments dip away from these provinces, east of south on the east, but with their dip swinging gradually to the southwest as the outcrop of the older rocks passes northwest into the Mississippi embayment. The inner border of the Plains is a 50- to 75-mile wide belt of Upper Cretaceous rocks overlapping upon the older formations; they are in turn buried by Tertiary rocks in the southern part of the state.

STRATIGRAPHY

The pre-Cambrian rocks are described, but need not be mentioned here. Facing page 80 the detailed Paleozoic sequences of different parts of the state and of Tennessee are given, with their equivalents in the general time scale of

the eastern United States. The column extends upward only into the Pottsville, or basal Pennsylvanian. The later Pennsylvanian, the Permian, Triassic, Jurassic, and Lower Cretaceous are entirely absent, but the Upper Cretaceous and formations of all the epochs of the Cenozoic are present. Each formation of all systems is described, and its fossils and their relationship to those of other parts of the country or the world are partially discussed.

STRUCTURE

The treatment of the structure of the state is very general; several cross-sections are given with the geological map. In the Piedmont is the familiar pre-Cambrian complex, with Paleozoic rocks in places infolded into it. In the Paleozoic area proper strong folds and faults affect the rocks southeast of a line through the Sequatchie Valley, itself an eroded anticline. Four main faults are named: that along the southeastern edge of the folded Paleozoic area, and those along the southeastern edges of the Coosa, Cahaba, and Warrior coal fields. Faulting is almost entirely by thrusting from the southeast.

Toward the Sequatchie Valley the structures become less intense. Northwest of it the structure is broadly synclinal, cross-sections showing the strata rising again into the deeply eroded northern part of the state. Outside of the strongly folded area the Paleozoics have a general gentle dip to the margin of the Cretaceous rocks of the Coastal Plain, and continue under them. An interruption of this dip occurs in the Hatchetigbee anticline and the Jackson fault at Tombigbee River, in the southeastern part of the state. In the Mesozoic rocks, little is said of structure other than their simple monoclinal dip away from the older rock outcrop. In Elmore County, at the edge of the Piedmont complex, the Eutaw has been let down in several blocks by faulting. In the Cenozoic formations is the same monoclinal dip. However, the surface expression of the two major Coastal Plain structures, the Hatchetigbee anticline and the Jackson fault, is in the bringing of older Tertiary beds to the surface.

GEOLOGIC HISTORY

The Paleozoic history deals with the predominance of the shifting of land areas and scenes of deposition, the formation of the coal in the Pottsville, and the final upheaval of the Appalachian revolution. The Mesozoic and Cenozoic history seems to be that of widespread vertical uplift, but with late local movement as expressed in the Hatchetigbee anticline and the Jackson fault. There are large breaks between the pre-Cambrian and the Paleozoic in this state, and between the Paleozoic and the Mesozoic systems. There is also a considerable break between the Mesozoic and Cenozoic.

SUMMARY

No mention of the application of the geology to oil prospecting is made, except in the possible development of the asphaltum in the Bethel sandstone and the Gasper formation of the Mississippian.

The deformation of the Paleozoics in the folded belt precludes oil possibilities in that area. In the rocks of this system outside of this belt no minor structures are described, though it is known that the formations are broadly warped. The fixed carbon ratio for the coal in the Pottsville is noted as having an average of 55 to 60 per cent; in a small area in Lookout Mountain and southwest of Birmingham it is lower. These areas are at the northwest edge of the strongly folded belt. For the Mesozoic and Cenozoic of the Coastal Plain is noted a simple monoclinal dip except in the Hatchetigbee anticline and the Jackson fault; it is possible that minor structures may be found in the area. No salt domes are known, nor the possibility of their occurrence mentioned.

As to source beds, there is a black shale in the Athens of the Ordovician, and the black Chattanooga shale of the Devonian is present. The source of the asphaltum in the Bethel and the Gasper, just above the Ste. Genevieve, may be from black shales at the base of the Gasper or some one of the several limestones in the lower half of the Mississippian, possibly the Ste. Genevieve. The Floyd shale at the top of the Mississippian is in many places black. Black clays are noted in the Eutaw of the Upper Cretaceous and the Naheola formation of the Midway group of the Eocene.

In the Mississippian are several sandstones, besides the Ste. Genevieve, a reservoir rock in other regions, and sands are plentiful in the Mesozoic and Cenozoic.

There is little in the report to encourage the oil prospector.

CLYDE G. STRACHAN

RECENT PUBLICATIONS

GENERAL

Methods of Applied Geophysics, by Erich Pautsch. The Gulf Publishing Company, Houston, Texas. Complete with formulae and graphically illustrated. 82 pp.; paper binding. Price, $6.50, postpaid.

FOREIGN

Manual of South American Oil Companies, 1927 edition. Megarel Publications, Ltd., 36 Wall Street, New York. Price, $1.00, postpaid.

Ores and Industry in the Far East, by H. Foster Bain. With a chapter on "Petroleum" by W. B. Heroy. Council on Foreign Relations, Inc., New York. 19 illus. 220 pp. Price, $3.50, postpaid.

The Oil-Shales of the Lothians (3d ed.), by R. G. Carruthers, W. Caldwell, E. M. Bailey, and H. R. J. Conacher. Geological Survey of Scotland, Edinburgh, Scotland, 1927. 274 pp., 75 figures, 12 plates. Price, 5*s*. 6*d*. net.

ILLINOIS

"Illinois Petroleum," *Press Bulletin Series No. 12, State Geological Survey*, Urbana. Deeper production in the Allendale oil field. Price, $0.25.

OKLAHOMA

"Analyses of Crude Oils from the Seminole District," by A. J. Kraemer. *Report of Investigations Serial No. 2824, U. S. Bureau of Mines,* Washington, D.C. Free.

"Upper Paleozoic Rocks of Oklahoma," by Charles N. Gould and Roy H. Wilson. *Oklahoma Geological Survey Bulletin 41.* Norman, Oklahoma. Price, $0.57.

"Oil Sands and Production Relations," by H. C. George and W. F. Cloud. *Oklahoma Geological Survey Bulletin 43.* Norman, Oklahoma. Price, $0.57.

THE ASSOCIATION LIBRARY

From Walter B. Jones:

"Petroleum Products in Shallow Wells in Alabama."

From R. K. Richardson:

"Die Geologie und die Salzdome im südwestlichen Teile des persischen Golfes."

From W. à Wengen:

"Phylogenetic Considerations of the Nummulinidae."

From Phillip B. King:

"The Bissett Formation, a New Stratigraphic Unit in the Permian of West Texas."

TECHNICAL PERIODICALS

The following periodicals, regularly received by the Association, may be consulted at Headquarters on the fifth floor of the Chamber of Commerce Building, Tulsa. Photostatic copies of any articles or pages will be made at cost for members of the Association. The usual charge is thirty cents a page. Address the Association, Box 1852, Tulsa, Oklahoma.

Annales des combustibles liquides (Paris)
Bulletin of the Geological Society of America (Washington, D.C.)
Economic Geology (Lancaster, Pennsylvania)
Engineering and Mining Journal (New York)
Földtani Szemle (Budapest)
Journal of Geology (Chicago)
Journal of the Institution of Petroleum Technologists (London)
Journal of Paleontology (Chicago)
La revue pétrolifére (Paris)
Mining and Metallurgy (New York)
Mining Journal (London)

National Petroleum News (Cleveland)
Oil Bulletin (Los Angeles)
Oil and Gas Journal (Tulsa)
Oil Engineering and Technology (London)
Oil Weekly (Houston)
Pan-American Geologist (Des Moines)
Petroleum Age (Chicago)
Petroleum Bulletin (Moscow)
Petroleum Industry (Moscow)
Petroleum Times (London)
Petroleum World (Los Angeles)
Petroleum Zeitschrift (Berlin)
Proceedings of the Geologists' Association (Colchester, England)
Revue de géologie (Liège)

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR ACTIVE MEMBERSHIP

George F. Barnwell, Weltevreden, Java, D.E.I.
C. S. Corbett, H. A. Buehler, J. S. Irwin

Robert Bellenden Hutcheson, Wilmington, Calif.
C. R. McCollom, Desaix B. Myers, Jack M. Sickler

Wilbur A. Oborne, Maracaibo, Venezuela, S.A.
S. W. Lesniak, L. C. Snider, M. N. Bramlette

Harry P. Stolz, Los Angeles, Calif.
Bart. W. Gillespie, F. C. Merritt, R. P. McLaughlin

FOR ASSOCIATE MEMBERSHIP

John A. Barnett, Dallas, Tex.
K. H. Schilling, Ernest Guy Robinson, D. H. Thornburg

Max Bornhauser, Dallas, Tex.
Angus McLeod, K. H. Schilling, Frederick Frei

DeVere V. Carter, Pittsburgh, Pa.
K. C. Heald, R. S. Knappen, R. E. Somers

Andrew Lee Christensen, Salt Lake City, Utah
F. G. Tickell, Eliot Blackwelder, Robert V. Anderson

Hugh D. Crider, San Angelo, Tex.
Hal P. Bybee, George D. Morgan, D. G. Barnett

Stephen W. Daszynski, Maracaibo, Venezuela, S.A.
Roswell H. Johnson, L. G. Huntley, R. E. Somers

Frank G. Evans, Jr., Dallas, Tex.
Charles M. Rath, John G. Bartram, Harry A. Aurand

John W. Garner, Caracas, Venezuela, S. A.
Ebert E. Boylan, F. I. Martin, Eugene C. Templeton

Willard Ellis Hall, San Angelo, Tex.
John I. Moore, D. H. Thornburg, W. van Holst Pellekaan
William T. Hoey, Cisco, Tex.
J. Earle Brown, J. H. Jenkins, J. Whitney Lewis
Forrest W. Hood, Tulsa, Okla.
C. J. Hares, Frank R. Clark, Max A. Pishel
J. Wilkinson Hoover, Fort Stockton, Tex.
T. J. Galbraith, Fred S. Wright, Henry J. Hawley
Marion King Hubbert, Cisco, Tex.
Stuart Weller, F. B. Plummer, Theodore A. Link
Winter I. Ingham, Amarillo, Tex.
William E. Hubbard, Eugene Holman, Dave P. Carlton
Warren J. Jackson, Shreveport, La.
Henry V. Howe, J. P. D. Hull, M. E. Wilson
W. Ross Keyte, Denver, Colo.
A. E. Brainerd, R. L. Heaton, E. W. Scudder
Colin V. McLaren, Eastland, Tex.
H. B. Fuqua, C. E. Yager, Ben C. Belt
James R. Mitcham, Brownwood, Tex.
F. B. Plummer, W. R. Berger, Ford Bradish
Henry J. Morgan, Jr., Tampico, Mexico
James B. Dorr, Charles E. Decker, H. C. George
Robert Muldrow, Jr., Norman, Okla.
B. E. Thompson, H. B. Fuqua, Ben C. Belt
Paul H. Reagan, Tocopilla, Chile, S.A.
Charles M. Rath, Hugh A. Stewart, Charles T. Lupton
F. W. Rolshausen, Houston, Tex.
Wallace E. Pratt, R. H. Goodrich, Dave P. Carlton
Maynard H. Steig, Tampico, Mexico
James L. Tatum, S. A. Grogan, P. H. Bohart
Clark R. Steinberger, Cookeville, Tenn.
E. R. Brockway, Charles E. Decker, V. E. Monnett
O. E. Stoner, Tulsa, Okla.
Frank A. Herald, H. E. Rothrock, Douglas B. Sterrett
Joseph H. Turner, Abilene, Tex.
R. E. Bending, Raymond C. Moore, Virgil O. Wood
Ward R. Vickery, Blackwell, Okla.
Robert B. Dunlevy, L. W. Kesler, Roy H. Hall

FOR TRANSFER TO ACTIVE MEMBERSHIP

John S. Barwick, El Dorado, Kans.
C. R. Thomas, John R. Reeves, Frank C. Greene
J. Marshall Brown, Fort Worth, Tex.
W. L. Goldston, Jr., R. R. Thompson, A. I. Levorsen

Marion H. Funk, Shreveport, La.
Leslie S. Harlowe, W. C. Spooner, L. P. Teas
Francis E. Heath, Dallas, Tex.
Willis Storm, Wallace C. Thompson, D. M. Collingwood
Julian Q. Myers, Laredo, Tex.
Sidney Powers, A. R. Denison, Dollie Radler
Frick C. Owens, Houston, Tex.
Wallace E. Pratt, Eugene Holman, D'Arcy M. Cashin
Georges Vorbe, Midland, Tex.
O. F. Hedrick, Charles E. Yager, Paul L. Applin
Leslie E. Wilson, Denver, Colo.
Charles M. Rath, Max W. Ball, Harold T. Morley

AT HOME AND ABROAD

The Geological Society of America and the Society of Economic Geologists hold their next annual meetings at Cleveland, Ohio, December 29–31, 1927.

W. STORRS COLE, of the Paleontological laboratory, McGraw Hall, Cornell University, Ithaca, New York, returned last summer from a stay of fourteen months in micro-paleontological work in Mexico.

LESTER C. UREN, professor of petroleum engineering in the University of California, published two articles on "Oil Mining" in the *National Petroleum News* last September.

GEORGE R. ELLIOTT has two articles entitled, "Potrero Much Drilled with No Evidence of Production" and "California Line Construction Keeps Pace with Oil Development," in the *Oil Weekly* of September 23, 1927.

ARTHUR KNAPP is the author of "Supply, Demand, and Price" in the *Oil Weekly* of September 23, 1927.

ERNESTO BARTH, director-general of mines and petroleum at La Paz, Bolivia, has an article in the *Oil and Gas Journal* of September 22, entitled, "Petroleum Resources of Bolivia and Outlook of the Industry."

T. E. SWIGERT, J. R. SUMAN, and P. B. ROBERTS have a paper on "Pumping Equipment and Engines" in the *Oil and Gas Journal* of September 22.

WALLACE E. PRATT is the author of an article entitled, "Recent Research in the Making of Oil," in the *Oil and Gas Journal* of September 29, reprinted from *The Lamp*.

MYRON C. KIESS has moved from Shawnee to Holdenville, Oklahoma.

W. L. RUSSELL, who has been in Venezuela during the past several months, has returned to New Haven, Connecticut. His address is 430 Temple Street.

VIRGIL B. COLE returned from Venezuela in August and is now with the Carter Oil Company at Shawnee, Oklahoma.

A. W. LAUER, of The Texas Company at Tulsa, Oklahoma, was engaged in geological work for his company in Kentucky last summer.

A. J. SMITH, recently with the Humphreys Corporation at Houston, is now geologist with the Pure Oil Company at Amarillo, Texas.

W. C. BEAN, in charge of geological work for the Roxana Petroleum Corporation at Wichita Falls, Texas, is now situated at Ardmore, Oklahoma, where he also has charge of the southern Oklahoma activity.

FREEMAN WARD is head of the department of geology at Lafayette College, Easton, Pennsylvania, and is not at Pennsylvania State College as erroneously noted in the *Bulletin* of July.

COY B. JONES, until recently with the Tidal Oil Company at Fort Worth, is now with the Union Oil Company of California, San Angelo, Texas.

F. W. PENNY, of the Phoenix Oil and Transport Company, who was in the United States during the past summer, has returned to his former station at Casuta Postala No. 1, Ploesti, Roumania.

KENT K. KIMBALL had charge of the general arrangement of the exhibits in the technical and scientific building at the Fourth International Petroleum Exposition at Tulsa, Oklahoma, September 24 to October 1.

GEORGE SAWTELLE, of the Kirby Petroleum Company, Houston, moved to San Angelo, Texas, last September.

R. R. THOMPSON, of Fort Worth, is reported to have mapped the geological structure of the new Mud Creek field in Runnels County, Texas.

FORD BRADISH, consulting geologist, is associated with J. P. JOHNSON, operator of Fort Worth, Texas.

RICHARD A. JONES, petroleum geologist of San Antonio, Texas, is the author of a paper, "Dissemination Almost Universal—Accumulations Rare," in the *Oil Weekly* of September 9.

ALLEN L. OWENS has returned from Venezuela, where he was in the employ of the Standard Oil Company of Venezuela, and is temporarily situated at 4529 Flora Avenue, St. Louis, Missouri.

The Central Petroleum Committee of the National Research Council has recommended to the American Petroleum Institute six additional research projects, Nos. 33–38. One of these, No. 33, is in geology, namely, "The effect of natural gas upon viscosity, surface tension, adhesion and general extractability of petroleum of various types. The problem would necessarily have to deal with different types of reservoir rocks, such as shales, cavernous limestones, conglomerates, sandstones, and unconsolidated sands, in so far as these can be secured and duplicated in the laboratory."

EUGENE ALLEN SMITH, member of the faculty of the University of Alabama for fifty-five years and state geologist for fifty-three years, died September 27, at Tuscaloosa, Alabama, at the age of 85 years.

MR. and MRS. W. K. CADMAN announce the birth of a son, Wilson Kennedy, Jr., on September 7, at Wichita, Kansas.

W. F. BOWSER, formerly at Texas Christian University, Fort Worth, has moved to San Angelo, Texas, care of T. L. Benson.

W. T. KELLER, formerly with El Aguila at Tampico, Mexico, moved last September to 53 Rütlistrasse, Basel, Switzerland.

A. W. DUSTON, of Tulsa, has resigned his position as chief geologist and manager of the land department of the Independent Oil and Gas Company to enter private geological practice, with offices in the Kennedy Building, Tulsa. Mr. Duston remains a director of the company.

JAMES W. KISLING, of the Amerada Petroleum Corporation, has moved from Enid, Oklahoma, to Shreveport, Louisiana.

C. L. RENAUD and T. M. PRETTYMAN, consulting geologists, announce the removing of their office from Cisco to the Alexander Building, Abilene, Texas.

E. H. FAHMY, of the Marland Refining Company, has moved to Berkeley, California.

T. A. BENDRAT moved from Montgomery, Alabama, to Keyser, West Virginia.

M. M. KORNFELD, of the Roxana Petroleum Corporation, has been transferred from Dallas to 2117 Post Dispatch Building, Houston.

ROBERT BARLING, recently with the Gulf Production Company at Wichita Falls, is now at 528 West Boyd Street, Norman, Oklahoma.

U. R. LAVES, of the Roxana Petroleum Corporation, has moved from Kerrville to 1258 Jeanette Street, Abilene, Texas.

RUAL B. SWIGER has moved from Sonora to Coleman, Texas.

VERGIL NEAL BROWN has moved from Oklahoma City to Tulsa.

THOMAS H. KERNAN is making his headquarters in Dallas.

O. A. LARRAZOLO, JR., is in charge of the geological work of the Huesteca Petroleum Company in Coahuila, Mexico.

W. Z. MILLER, of Tulsa, is with the Gypsy Oil Company in Colorado.

JAMES BOWEN is chief geologist of the Panhandle Refining Company at Wichita Falls.

HENRY HUMMEL has resigned from the White Eagle Oil and Refining Company and is engaged in consulting work in Fort Worth.

ALVIN P. LOSKAMP represents the Barnsdall Oil Company at San Angelo.

L. H. FREEDMAN is an independent operator at Fort Worth.

CLARENCE E. HYDE, vice-president of the Marland Oil Company of Texas, spent September in California on a business trip.

GEORGE DUNN is geologist for the White Eagle Oil and Refining Company at Tulsa.

CALVIN T. MOORE has resigned from the Coline Oil Company and represents the Silurian Oil Company at Fort Worth.

EVERETT C. PARKER, of the Marland Oil Company of Oklahoma, has returned to Ponca City after a summer in Canada.

R. D. MCCLUER, of Corsicana, Texas, is mapping the Edwards plateau.

MR. and MRS. JOHN F. HOSTERMAN announce the birth of a daughter, Barbara Jean, at Tulsa, Oklahoma, September 6, 1927. Mr. Hosterman is geologist for the Amerada Petroleum Corporation.

ROSWELL H. JOHNSON has returned from a trip to Sverdloak in the eastern Urals.

JAMES F. PEPPER has moved from Amarillo, Texas, to Pulteney, New York.

LEROY T. PATTON, head of the geology department of Texas Technological College at Lubbock, announces that WILLIAM A. P. GRAHAM and MERRILL A. STAINBROOK have been added to the geology staff as associate professor and assistant professor, respectively.

DAVID M. LOGAN, representative from Okmulgee, introduced a bill in the Oklahoma state legislature this year providing for an expenditure of $31,000 a year for topographic work, half to be paid by the United States government and half to be taken from the highway construction fund of Oklahoma. The bill became a law, and the following quadrangles are to be mapped in 1927: McLoud, Sac and Fox, Drumright, Yale, Skedee, Gray Horse, Kaw, and Belford.

JOSEPH JENSEN, chief petroleum engineer of the Associated Oil Company, is now situated at the company's main office in San Francisco.

JEROME B. BURNETT, of the Lago Petroleum Corporation, Maracaibo, Venezuela, was in New York last summer and has now returned to Venezuela.

FRED H. KAY, of the Pan-American Petroleum and Transport Company, 120 Broadway, New York City, went to Venezuela in October for a six weeks' stay.

ARIE VAN WEELDEN of Dallas, Texas, and Delft, Holland, and Florence Swain, daughter of Mr. and Mrs. J. C. Swain, of Riverside, California, were married on September 30 in Trinity Episcopal Church at Tulsa, Oklahoma. Mr. and Mrs. van Weelden sailed early in November for a three months' tour of Europe. On their return they will be at home in Dallas, Texas, where Mr. van Weelden is a geologist for the Roxana Corporation.